PROCEEDINGS

—OF—

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

PITTSBURG, PA.

VOL. XVI.

1900.

CONTENTS.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The twentieth annual meeting of the Engineers' Society of Western Pennsylvania, was held in the Lecture Room of the Society's House, 410 Penn Ave., Pittsburg, Pa., Tuesday evening, Jan. 16, 1900, the President, Mr. H. J. Lewis, being in the chair and forty-eight members and visitors present. The meeting was called to order at 8:35 o'clock and the minutes of the preceding annual meeting were read and approved.

The following report was read by the Treasurer:

REPORT OF TREASURER,
FOR THE YEAR ENDING JANUARY 16, 1900.

1899.	RECEIPTS.					
January 17.	Balance					$ 36.07
	Dues to January	1896,	at $5.00	1	$ 5.00	
	" " "	1896,	" 7.00	1	7.00	
	" " "	1897,	" 5.00	6	30.00	
	" " "	1897,	" 7.00	6	42.00	
	" " "	1893,	" 5.00	6	30.00	
	" " "	1898,	" 7 00	10	70.00	
	" " "	1899,	" 5.00	5	25.00	
	" " "	1899,	" 7.00	26	182.00	
	" " "	1899,	" 3.50	1	3.50	
	" " "	1900,	" 5.00	59	295.00	
	" " "	1900,	" 7.00	261	1827.00	
	" " "	1900,	" 2.50	1	2.50	
	" " "	1900,	" 3.50	9	31.50	
	" " "	1901,	" 5.00	1	5.00	
	" " "	1901,	" 7.00	3	21.00	
	" on account				19.00	
	Initiation Fees, at $5.00, 58				290.00	
	Rent of Rooms				936.00	
	Advertising				318.00	
	Sale of Proceedings				115.50	4255.00
						$4291.07

EXPENDITURES.

Rent	$1500.00	
Salary of Secretary	600.00	
Printing	951.87	
Office Expenses	226.53	
Illustration	67.50	
Repairs and Improvements	54.65	
Rent of Stereopticon	22 00	
Library	57.95	
Gas	59.34	
Addressing Machine	70.70	
Stenographer	71.00	
Periodicals	26.00	
Insurance	40.00	
Commissions	31.80	
Lunches and "Smoker"	10.72	
		3790.06
Balance		501.01
		$4291.07

Respectfully submitted,

A. E. Frost,
Treasurer.

A vote of thanks was tendered Mr. Frost for his long and faithful service as Treasurer of the Society.

Mr. G. S. Davison—If the Treasurer's report is still in order, I would like to say that I have noted a couple of points that the Treasurer has not referred to. One is that in all our prosperity, there was but $57.95 spent on our library. There might have been more done in that direction and I hope we will be able to do so in the future. The fact that we have a good surplus to start on would certainly give us heart to do something for the library. I was much pleased by the showing of the Treasurer. Another fact brought out was that while we pay $1500 rent for this building, still we have a credit of $936 from sub-letting, which makes the rent of our quarters only $564. I call attention to this fact for the reason that it was a very serious question at the time that we thought of having such quarters as these, whether the Society could afford to leave a place where they were getting rent free and pay anything for rent. A committee was appointed to secure

quarters with the instructions that they were not to exceed $900 annual rent. The committee made arrangements accordingly, and I am pleased to see that it has not cost the Society $900 any year, and I believe it has cost less this year than any other.

Mr. H. J. Lewis—We were not sure that we would have such prosperous times when we took these quarters.

Mr. Frost—If you will look back over the books, month by month, you will see that there were many months of adversity, and one where the account in the treasury was down to $20, but there has been a very happy change in the affairs during the last few months.

Mr. H. J. Lewis—The auditing committee has passed upon this report of the Treasurer and their signatures are here appended.

It was voted that the report of the Treasurer be received and filed.

The following report was read by the Secretary:

Membership at close of year ending January 17, 1899......		363
At the Annual Meeting, January 17, 1899, there were eight (8) names dropped from the roll.........	8	
There were eleven (11) resignations and four (4) deaths during the year..	15	
	25	
During the year two (2) of the applicants elected in 1898 matriculated, and seventy-six (76) applicants were elected members of the Society during 1899, and of these fifty-five (55) matriculated..............................	57	34
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The average attendance at the monthly meetings of the Society during the year was thirty-eight (38).

Reginald A. Fessenden, *Sec'y.*

Prof. Fessenden pointed out the fact that the Society had, during the last four years gained practically a thousand dollars; that in 1896 they ran behind $420.13, while this year they have a credit of $501.01. He also called attention to the fact that the amount actually spent on the library was really over

$200.00, as $150.00 of subscriptions per annum were received and paid for by exchanging our own proceedings, so that the item "sale of proceedings" really amounted to about $265.00 instead of $115.00. It was voted that the report of the Secretary be received and filed.

For the Program Committee, Mr. C. M. Albree reported that the committee had papers promised for five or six meetings ahead, but everybody was so busy now that it seemed almost impossible to find anyone to take the trouble to prepare a paper.

For the House Committee, Mr. G. W. Schluederburg reported that there had been an effort made by the committee to hold the lease, and that they had some correspondence with the owner who will be in Pittsburg soon. An offer had been made to take the house for a number of years at the same terms.

Mr. William Bradford reported for the Reception Committee that the finances were in good shape as far as they had gone; that there was a slight deficiency which they hope to make up the first part of February. He also stated that the committee would like every member to do his utmost to sell tickets for the banquet.

Next in order was the report of the Board of Direction.

The Board of Direction recommended the expulsion of thirteen members for non-payment of dues.

It was voted that the names be stricken from the rolls.

Prof. Fessenden stated that all those wishing Society buttons should leave their names with the Secretary, and when twenty-five names were secured they would send for the buttons.

The President then read his annual address.

PRESIDENT'S ANNUAL ADDRESS.

The year just past, and possibly the one before us, marks the crest of one of the great tidal waves which occur in commerce and industry at intervals of about two decades. After a period of depression during which the whole nation learned to purchase and consume only for its bare necessities and in which each producer strove to bring forth the maximum of product with the greatest possible economies, we now find ourselves with a comfortable balance of foreign trade in our favor, and capital long idle or poorly invested, ready to embark in enterprises which promise a fair profit.

In 1879, our country had recovered from the panic of '73, and then entered upon a period of activity similar to that of the present except along different lines. At that time, the demands upon us for flour and beef were so great, and pushed prices to such a point that it was at once profitable and necessary to develop new areas of production. This was accomplished by large extensions of railroads into new territory and the encouragement of emigration thereto of a population of producers. Labor-saving machinery in the production of farm crops was well introduced previous to this time, and, under the favorable conditions of large demands and high prices, its use and improvement was greatly stimulated. The agricultural population was therefore actively and profitably employed, large forces of consumers were busy with the construction and operation of railroads, while the mines, the mills and the workshops were busy with needed supplies. Great consolidations of railroad properties into trunk lines were completed and necessary feeders were built, our remaining agricultural areas were rapidly settled and developed, while great industrial communities were formed where agricultural products were put in shape for consumption and where supplies were produced for the rapidly specialized demands of modern civilization.

For a time, the general activity of the country supported

a demand for all its products, and at good prices, but this in turn stimulated production until it finally reached the point of internal competition. Our farming areas were extended until they not only included everything, having sufficient rainfall but also arid regions which could only produce by irrigation and at times of comparatively high prices. The building of railroads was so hotly pushed in the race for strategic control of territory that different lines often became competitors before either one had developed a paying traffic. The workshops were pushed until the farmers were supplied with implements; the railroad with rails, cars and engines and other industries were loaded up in like manner until the problem of production became more a matter of maintenance of the old than the construction and sale of new machinery. The development of mines, on account of the great areas available and the small investment required, was carried forward until competition between them became their worst enemy.

The flush times of '79, therefore, gradually drifted into the depression of '83, which was the natural result of the causes above mentioned, together with others more obscure. After a short lull, however, the demand in many lines began to increase, and the general condition of the country was easier. About this time, however, the American farmer, who had been finding a foreign market for his surplus breadstuff, began to feel the competition of Russia, Egypt and India. He was thus in a position from which he knew not how to turn back with profit as the demand for beef and pork was spoiled by the increased number engaging in their production as the prices of breadstuff fell. The whole agricultural community was, therefore gradually reduced to a condition of the most rigid economy. While the farmer was wading gradually deeper into misfortune, many of the industries of the country accompanied him, while others were temporarily bolstered up by a structure of legislation and combination as to prices; but even these suffered from decreased market.

Unnatural conditions cannot long survive, however, and in '93 these latter were suddenly dropped into deep water along with the rest. Many plants were closed down and only those with low cost of production were able to continue. It was a clear demonstration of the fact that artificial conditions cannot long endure against natural causes. In this connection, it may be noted that nearly all of the Western roads who attempted to protect their communities by giving low long-haul rates to put them in competition with more fortunately located producers in the East, were forced into bankruptcy.

The panic of '93 left just two alternatives before every business man, manufacturer and corporation; either to show complete ability to settle all outstanding obligations in full or be declared insolvent. Settlement day had come, and many parasites were removed from the business world, obsolete plants were closed and unsound corporations went into liquidation. The lesson of economy was forced upon all, from the greatest corporation manager down to the poorest laboring man. The obligations of men and corporations were either wiped out or scaled down to a paying basis. Econimies in production and consumption alike, were forced upon those who had heretofore neglected them. Our imports were gradually reduced and under the stimulus of cheapened production and lower prices, an increased stream of exports flowed outward, until finally the balance of foreign trade was in our favor and our own people began to absorb at a greatly reduced price, many of our securities formerly held abroad. During this time, we wore out everything from old machinery to old clothes and laid the sure foundations for a healthy demand when the proper time should arrive. The production of everything, from wheat to pig iron, was restricted by natural causes until demand finally overtook the supply.

The lessons of caution and economy had been so well learned that our improved condition existed for some time before serious efforts were made to provide for the rising

wave of demand; but finally it burst all bounds, and in the year just past the producer found his condition changed from that of a seeker of business to where the business eagerly sought him. Prices eventually shot upward but not until a great volume of production had been tied up at the old rates. This has now been fairly well cleared away and producers are, at present, in position to receive full benefit of improved conditions. Increased capacity is demanded to take the place of former plants abandoned because obsolete and to supply the additional needs of a growing population. The reduced prices of many of our products during the time of depression carried them into new fields in which they persist and must be provided for.

A period of activity is before us until the country is supplied with new material and appliances according to its needs and we settle back to the maintenance of the old in place of the production of the new. The volume of exports developed during our period of low prices, is a hopeful sign and may be of great help when the home demand for new material begins to decline.

The period above has been thus roughly sketched for the reason that in no other of the same length, has the American engineer been called upon for the solution of so many great and varied problems, and, in no other has he been accorded so much of professional recognition.

Following up the expansion of railroading with which it began, he has been called upon to locate great and small systems, often over the most difficult ground in the country. The problem of roadway, with its auxiliary structures and construction, has been worked out by a process of exclusion until all roads are now following the same general lines, instead of the chaos of design and construction of twenty years ago. The efficiency of motive power and rolling stock has been fully doubled in every respect. Terminal problems, then in their infancy, have in the meantime demanded, if any-

thing, more ingenuity than the location of the trunk lines which required them. The abolishment of grade crossings, especially in cities with heavy street traffic, has required careful and ingenious handling, not only in construction but in providing for train movement while changes were made.

The different mining interests, from which so much of the railroad's traffic is derived, and upon which their operation so greatly depends, have increased in full proportion to transportation facilities. As to mining methods, twenty years ago we were largely dependent on foreign engineers and foreign methods, while to-day the American mining engineer and his distinctive methods have won a recognition at home and abroad.

The great and rapid concentration of population in cities which came with railroad development, has set new and difficult problems before the engineer. Water supply, sewering and sewage disposal, street construction and cleaning, city and suburban rapid transit, lighting, heating, power distribution, telephonic communication, and vertical construction of buildings have made strides which can hardly be realized until we reflect that until 1879 the telephone was little more than a curious plaything, while the dynamo and arc light were more of laboratory experiments than commercial facts. On all of these things the engineer has placed his mark with a bold yet careful hand.

Twenty years ago, we were dependent upon foreign sources for a large percentage of our supply of the useful metals, notably iron and steel. With the development of our mines and railroads, has come the construction of furnaces and mills more than ample for our own needs and under the hard schooling of the late depression, we have developed economies of method which may enable us to more than balance our debts of foreign material, incurred in the past.

The swings from general prosperity to depression are felt by the engineer in a practical way both as to their direct effect upon his income and in the variation of problems set before

him. In flush times he is called upon to plan a great amount of work with little time for reflection, and this is rushed through with more or less disregard as to cost. These things are then called upon to go through a time of depression and still earn dividends. It is impossible to change this, as things are now ordered, but it is no less a matter for regret that problems of great moment which are set before us for hurried solution, could not have the benefit of reflection during some of our leisure hours. In slack times we are called upon to aid in the work of retrenchment, both as to ways and means, and also as to our incomes which share the general pruning.

The past year has been a remarkable one in many ways. The business of the country has shown a recuperative power, both as to volume and price, which, even those best informed could hardly foresee. Great combinations of capital have been built up into industrial enterprises whose efficiency and economy should be greatly increased thereby. Those of them which include mainly, well-built modern plants with low cost of operation, require only careful, broad-minded management to endure. Others, which have taken over a large percentage of old inefficient plants, can hardly escape disaster with a consequent weeding out of that which is obsolete.

Heretofore, trunk line railroads have been the most notable examples where large blocks of capital have been controlled under one head. If the example of the best managed roads is worth anything, the great industrial corporations will avail themselves of the best obtainable engineering service, and the young men starting in this department will be utilized, after proper training, in operation and management.

The total of horse power in steam engines and other prime movers, which was added to the world's stock during the past year is easily greater than ever before, and the amount of our contracts abroad show that we are not falling behind in design.

The exile of the horse from the city may now be looked for with confidence, and this is a matter for congratulation

from both the sentimental and economic standpoint. The city horse is an expensive means of locomotion, his life is not pleasant, and his place on the breeding farm is needed for beef cattle to meet our growing demands in that line.

During the last twenty years the engineering profession has, by the merit of its work, won a fairly full recognition of the value of services rendered, and let us hope that at the end of the next twenty, they may come to be so rewarded as to enable the worn-out engineer to spend his declining days in peace and comfort.

The President announced that the next order of business would be the election of officers for the ensuing year.

The President announced candidates for offices reported by the Nominating Committee as follows:

OFFICERS FOR 1900.

President—W. A. Bole, term expires 1901.

Vice-President—C. F. Scott, term expires 1902.

Directors—Gustave Kaufman, term expires 1902; C. B. Albree, term expires 1902.

Secretary—Reginald A. Fessenden.

Treasurer—A. E. Frost.

On motion of Mr. Davison it was voted that nominations be closed and the Society proceed to ballot. Upon counting the ballot the tellers reported that the candidates had each received thirty-eight votes, and the President declared them duly elected.

The following is the list of officers and members of committees for the year 1900-1901.

OFFICERS FOR 1900

GENERAL SOCIETY.

PRESIDENT.

W. A. Bole.

VICE PRESIDENTS.

H. W. Fisher, Term expires 1901.

C. F. Scott, Term expires 1902.

DIRECTORS.

P. T. Berg, Term expires 1901.

F. C. Phillips, Term expires 1901.

Gustave Kaufman, Term expires 1902.

Chester B. Albree, Term expires 1902.

SECRETARY.

Reginald A. Fessenden.

TREASURER.

A. E. Frost.

CHEMICAL SECTION.

CHAIRMAN.

James O. Handy.

VICE CHAIRMAN.

Alexander G. McKenna.

DIRECTORS.

Dr. K. F. Stahl, Dr. E. S. Johnson.

SECRETARY.

G. O. Loeffler.

STANDING COMMITTEES.

RECEPTION COMMITTEE.

Chas. Hyde, Chairman, E. E. Keller,
Victor Beutner, R. Moldenke, Charles Fitzgerald,
R. T. Stewart, Ralph Crooker, Jr.

HOUSE COMMITTEE.

F. Z. Schellenberg, Chairman, J. M. Camp,
E. S. McClelland, G. E. Flannagan, William Metcalf.

LIBRARY COMMITTEE.

Richard Hirsch, Chairman, N. C. Wilson,
K. F. Stahl, C. B. Connelley, Percy H. Thomas.

PROGRAMME COMMITTEE.

Chester B. Albree, Chairman, Alex M. Gow,
Wm. B. Phillips, W. E. Snyder, Frans. Engström.

Mr. Lewis—It gives me great pleasure now to turn the Chair over to so worthy a successor as Mr. Bole.

Mr. Bole—I wish to thank you all for the honor conferred upon me in electing me to follow in the steps of such an illustrious line of past presidents. I shall endeavor to render to render to you as good service as I am able to.

Mr. C. F. Scott—It has been talked over from time to time, and motions made, and persons appointed to carry into effect motions in regard to our past presidents. We have a good fresh one now, and I think we should have some illustrations of our by-gones to decorate the walls of our Society Hall. I think it would be a good start to get a portrait of our last one. It would be a beauty and a joy forever.

It was voted that the retiring President be especially requested to carry out the matter which he had so urgently brought forward with regard to other Presidents, and he be requested to set an example and furnish a picture of himself to be hung in the Society Hall, and that his predecessors be requested to follow his lead.

On motion the annual meeting was adjourned at 9:30 P.M.

Reginald A. Fessenden,
Secretary.

REGULAR MEETING.

The two-hundred and first regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture Room of the Society's House, 410 Penn Ave., Pittsburg, Pa., Tuesday evening, Jan. 16, 1900, forty-eight members and visitors being present. The meeting was called to order at 9:30 by the President, Mr. W. A. Bole.

The minutes of the previous meeting were read and approved.

For the Board of Directors, the following applicants were reported as passed and to be voted for at the next regular meeting:

EDWIN YAWGER, - - -	Mechanical Engineer, With Westinghouse, Church, Kerr & Co., Westinghouse Bldg., City.
FRANCIS BROWN, - - -	With Brown & Zortman Machinery Co., No. 1 Wood St., Pittsburg, Pa.
ELLIOTT M. SERGEANT, -	Draughtsman, With Westinghouse Electric and Manufacturing Co., 6336 Marchand St., Pittsburg, Pa.
WILLIAM JOS. WEBSTER, -	Manager, Hercules Powder Co. and Atlantic Dynamite Co. of New Jersey, 248 Mathilda St., Pittsburg, Pa.
CHARLES W. WRIGHT, -	Superintendent, Aliquippa Steel Works, 334 Sheridan Ave., Pittsburg, Pa.
MILNOR. P. CLARK, - -	Draughtsman, For Julian Kennedy, Mechanical Engineer, 803 E. Park Way, McKeesport, Pa.

Mr. G. S. Davison—We were all very much impressed by our President's remarks as to the financial condition of the world. We were further impressed by the Treasurer's report of our own condition. I also note the report of the Chairman of the House Committee that there is great danger of our being

compelled to seek new quarters, when our present term expires. It seems to be an opportune time to bring forward the question of this Society owning its own house, and I would like to test the feeling of this meeting on that subject. I, for my part, have always wished to see this Society in its own building and I believe the wish is a general one. We now have $500 in the treasury and the question is, what will we do with it? If we are ever going to create a building fund, now is the time to do it. When the times were hard, we were too poor to do anything in the way of getting this fund together. I am now informed by our President that times are so flourishing that we are too busy making money to think of donating any. It strikes me that the only way to start this thing toward success is to begin right now among ourselves, and see what can be done. When we show a disposition to help ourselves we can go to our wealthy friends outside the Society and consistently ask financial assistance.

In order to sound this meeting, I would state that it would be a great pleasure to me to be the first subscriber to the House Fund, of a sum not less than $100.00 when it has been determined that we will go ahead, reserving the right to increase the amount as circumstances may determine.

Mr. W. G. Wilkins—Not to be behind my ex-partner, I will follow suit and subscribe $100.00.

Mr. W. B. Phillips—I will also subscribe $100.00.

Mr. W. A. Bole—As a matter of fact the owner of this property has made a proposition to the Society to sell this property. It is something like this—That she will sell the property for a sum of money not exceeding $29,000, and if I remember rightly, her terms were $2,000 in cash, and a mortgage at 6 per cent. on the balance. I would like to ask Mr. Davison to define what would be a safe sum to start in on such a sum as this.

Mr. G. S. Davison—I would like to see this Society raise within its own membership not less than $10,000. Of course,

we cannot determine right here the best thing for the Society to do, and I think some special committee will have to take this question up before sixty days in order to determine that for the Society. We are paying rent now at the rate of $1,500 a year, which is 6 per cent. on $25,000. I would think with $10,000 from our members, it would be a very tidy sum to start out with to raise $10,000 more.

Mr. C. B. Albree—I would like to ask for a little information as to Mr. Davison's idea. It seems to me that a good deal of the time it would not be of much advantage to us, unless we used it as a club house. We have now a very pleasant place to meet; and you will find the interest on $28,000 would be $1,680, and taxes, etc., would bring that up to $2,280. We could only meet once a month, unless we wanted to make a club house of it; that would be a different thing. I do not want to throw cold water on anybody's plans, but it seems to me we should have some better reason for putting so much money into the thing.

Mr. Davison—Our dues in this Society have, in my opinion, been too low, which means that our members have not paid in the past what they should have paid to entitle them to membership. I have expressed myself on this point before. Personally, I owe the Society something, and I am taking the view that any donation I make is an endeavor to square accounts.

Now as to the other point—What good will it do the Society to own its own property? I think it will do the Society a great deal of good to have the public know that the Engineers' Society of Western Pennsylvania is able to own its own property. It will make the Society more substantial, make membership more inviting from a sentimental point of view, and more valuable from a business standpoint.

Mr. Jones—While I sympathize with Mr. Davison as to what it may mean to the Society in the future, I can hardly see that his plan is a practical one. Unless you have a large

number of members, the scheme will have to be put on another basis. Probably one-half the members who could not afford to subscribe would want to do just as well as their fellow members did. I think that a subscription by one-half or one-fourth of the members would be a sore point with them, simply because they would not have the financial ability to do the same. I think that for the Society to own its own building would be the proper thing. That is the case of the American Society of Mechanical Engineers. I believe that a start on this point of the Society owning its quarters would be for the benefit of the Society. There should be a plan of doing this by which members could subscribe to a certain amount of the bonds of the company. Each member will then always have something to show for his share in the property of the Society. I only throw this out in a broad way. The Treasurer's report shows a very prosperous condition, but of course that sum is not going to carry us along and pay interest on money, etc. If you keep the fees as they are or increase them, I think you will find ample return in the increase of membership. I do heartily agree with Mr. Davison that it would be a great boon for the Society to be in its own building. I know of another instance of this kind in which a few members offered to subscribe from $1000 to $8000. It did not work. They came down finally to such a system as I suggest, by which each man would have something to show for his share in it. You will find that voluntary subscriptions won't work.

Prof. Fessenden—When this thing was brought up, I went around to a real estate agent and asked him to find out what this property was probably worth. I got a report from him. He said it was estimated at about $35,000, so we would get a bargain in it if we considered this a suitable place. I took the liberty of speaking to two or three men in regard to this matter, and these gentlemen expressed their willingness to assist the Society. They are men who have considerable wealth and I think we could get help from some outside sources.

Mr. W. G. Wilkins—I think at the price this property is offered it would be a good business investment for the Society to own this building and I believe if we could get this property for $29,000 we should do so.

Mr. R. G. Moldenke—I believe that the idea of issuing bonds is a good one. I have seen a great many things run in this manner, too. I believe that the house should be bought almost at once and bonds issued for the full amount. The first thing to do is to get the house. I am heartily in favor with Mr. Jones' remarks.

Mr. J. P. Leaf—Mr. Jones' proposition strikes me very favorably. I was interested in the armory, which was built on a similar plan. The thought came to me as I was sitting here that there is none of us but who can spare the coming year at least one week's wages. Three hundred members would amount to a snug sum. Figuring on a week's wages from each member of the Society, we would have several thousand dollars. I don't care who it is, he likes to have something to show for his investment, and I think issuing bonds on the par value of the property is a good thing. I find in all bodies that people who are most willing to give, are not always the most able.

Mr. G. S. Davison—I would like to say in regard to the bond scheme that we must have some cash subscriptions to protect the bonds to be issued. It is this we are trying to get, and the more enthusiastic we become the more money we can raise, and thus reduce the necessity of the bonds to a minimum. I hope this matter will be put into the hands of a committee to proceed at once.

Prof. Fessenden—I would ask Mr. Jones what these bonds drew.

Mr. Jones—If I remember correctly about $3\frac{1}{2}$ or 3 per cent. If had been at $2\frac{1}{2}$ per cent. interest they would have been taken as well. In regard to this property, I think that the price stated is dead cheap for it. Of course if you have

the feeling that you could raise the money without any assistance from outsiders, that would be nice. I only speak from my own experience. I have never known the voluntary subscription plan to work except in churches or something of that kind.

Mr. H. W. Fisher—I don't think we should buy this property unless it would be suitable for an Engineers' Club House. I think it would be better for us to go on a few years and get a property we would want for an Engineers' Club House. We might be able to get a more desirable property and a better located property than this is. I think we ought to be careful to see our way clear to pay for the property before going into the thing.

Mr. W. G. Wilkins—My idea to invest in this property is that it is a cheap property at the present time. If afterwards, we should be able to find a better location, we could sell this and buy another place. I don't know where we could find a better one at the present time.

Mr. T. H. Johnston—The subject is a pretty broad one and needs a good deal of consideration before we go into it. I think we should appoint a committee to look over the different points and report to the Society.

Mr. W. A. Bole—The question of what shall we do with past presidents, is a serious one to settle. I would like to ask Mr. Johnston if he would think that a committee comprising the past presidents of this Society would be a suitable committee to endorse the most important financial deal of our history.

Mr. T. H. Johnston—I think there are some better able to deal with financial questions than your past presidents.

It was voted that a committee of five, consisting of members of the past presidency, be appointed to consider the matter of collecting subscriptions to a fund of money to be applied upon a permanent residence for the Society.

The President then appointed the following committee:—Geo. S. Davison, Chairman; T. H. Johnston, Wm. Metcalf, Emil Swensson, John A. Brashear.

On motion, the Society adjourned at 10.10 P. M.

REGINALD A. FESSENDEN,
Secretary.

MEETING OF CHEMICAL SECTION.

The Eighth Annual Meeting of the Chemical Section was held January 18th, 1900.

Chairman, E. S. Johnson.

Attendance, 12.

The minutes of the last annual meeting were read and approved.

Dr. Phillips, for the Committee on Literature, read a number of abstracts.

Ballots were then distributed and the following officers for the ensuing year unanimously elected:

Chairman—J. O. Handy.

Vice Chairman—A. G. McKenna.

Secretary—G. O. Loeffler.

Directors—Dr. K. F. Stahl, Dr. E. S. Johnson.

The retiring chairman then read an address on the Synthesis of Indigo.

(This address will be published later.)

After discussion of the paper the Section adjourned at 10.30 P. M.

The regular monthly meeting was called to order by the new chairman and adjourned without transacting any business.

A. G. MCKENNA, *Sec'y C. S.*

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and second regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture Room of the Society's House, 410 Penn Avenue, Pittsburg, Pa., Tuesday evening, Feb. 20th, 1900, thirty-six members and visitors being present. The meeting was called to order at 8:30 o'clock by the vice-president, Mr. H. W. Fisher.

The minutes of the preceding meeting were read and approved.

Prof. Fessenden stated that owing to a mistake, a remittance from Mr. Edwin H. Beazel for his dues was not received in time and that his name was among those which were dropped from the list at the last meeting, and that the Board of Direction recommended to the society that Mr. Beazel be reinstated. Motion carried.

For the Board of Direction, the following applicants were reported as passed and to be voted for at the next regular meeting:

E. M. HERR, - - . -	Assistant General Manager, Westinghouse Air Brake Co., Pittsburg, Pa.
LOUIS W. FOGG, - - -	Mining Engineer, American Coke Co., Latrobe, Pa.
FRANK S. JACKMAN, - -	Superintendent, Pittsburg Mfg. Co., 28th and Railroad Streets, Pittsburg, Pa.
JAMES DINSMORE WHITE, -	Civil Engineer, 730 Park Building, Pittsburg, Pa.
RICHARD LESSNETT SMITH,	Civil Engineer, 1011 Park Building, Pittsburg. Castle Shannon, Pa.

The following gentlemen were balloted for and duly elected to membership:

FRANCIS HERBERT BROWN,	Manufacturer, Brown & Zortman Machinery Co., No. 1 Wood St., Pittsburg, Pa.
MILNOR P. CLARK, - -	Draughtsman, For Julian Kennedy, Pittsburg, Pa. 803 E. Park Way, McKeesport, Pa.
ELLIOT M. SERGEANT, - -	Draughtsman, For Westinghouse Electric & Mfg. Co., East Pittsburg, Pa. 6336 Marchand St., Pittsburg, Pa.
WILLIAM JOSEPH WEBSTER,	Manager, Of Hercules Powder Co., and Atlantic Dynamite Co. of New Jersey, 248 Matilda St., Pittsburg, Pa.
CHARLES W. WRIGHT, - -	Superintendent, Aliquippa Steel Works. 334 Sheridan Avenue, Pittsburg, Pa.
EDWIN YAWGER, - - -	Mechanical Engineer, With Westinghouse, Church, Kerr & Co., Pittsburg Office, Westinghouse Building, Pittsburg, Pa.

The Library Committee reported that they had not done any work yet, but they were arranging to get at it soon.

Mr. Bradford reported for the Reception Committee as follows:

Received from sale of tickets for Banquet, Feb. 8, 1900			$648.00
Expenses:	Supper for 161 at $3.00	$483.00	
	Cigars	22.20	
	Music	30.00	
	Printing	38.85	
	Flowers	50.00	
	Balance due Committee on account of Smoker	8.30	
			$632.35
Balance due Society			$ 15.65

It was voted that the report of the Reception Committee be accepted, and that the Reception Committee, and especially

the chairman of it, should be tendered the thanks of the society for the excellent work they had done.

MR. H. W. FISHER—We will call on Mr. Davison, whom we appointed at the last meeting in reference to the House Committee, to report their progress.

MR. G. S. DAVISON—The committee would say that we have received very few replies, but we have heard a number of expressions of opinion, however, and have about come to the conclusion that we will have to formulate a better plan of action. We will proceed to do so at once and probably by the next meeting we will have such plan formulated.

It was reported at the last meeting that our five years' lease on this property expires on the first of April. I find this to be an error. Our lease does not expire until one year from the first of April. It will give us more time to formulate a good plan and see about the financial end of it.

MR. C. F. SCOTT—One point has occurred to me which, doubtless, has occurred to other members of the society. A great many of the members do not feel able to join in a contribution of $100. Many of the members would make such contributions, but there are a great many who do not feel able to do so. It seems to me that if a general appeal were made to the society, the members as a whole would not give more than the whole membership fees would amount to. If the membership should be called on to contribute, say $10.00 each, it would amount to $3,000 or $4,000. I have known of such things to be done in times past where a society went to work to put up its own building. And I also think it would be found successful to organize a stock company and make the shares $10, or perhaps $50, and the members take stock in it. A building in this part of the city ought to be a good investment even if we should put it up as a regular financial investment, with no contributions asked from any person. It might be well if the members of the society should have first chance to subscribe to the stock, and then if outsiders want to come in there is no objection.

Mr. G. S. Davison—The suggestion about the contributions is all right but it should be borne in mind by the members that it is important that the sum of money left for the mortgage should not be so great that the interest on it will amount to more with the taxes added than our present expense. It is the idea of the committee that a sufficient amount of cash should be subscribed so that the amount remaining would not be so great but that the interest upon the same would not exceed the ordinary rent for our rooms, otherwise we would not be bettering our condition. I believe we have a much lower offer for this property than we will ever have again and I think we had better embrace the opportunity and get it now.

Prof. Fessenden—It is not a certainty that we can rent this building for $1,500 when the lease has run out; in fact they have asked for a larger rental already. I think they have asked for about $300 per year increase. I would ask Mr. Davison at about what interest he thinks those bonds can be placed. Does he think they could be placed at 3 or 4% ? If so, it would be a good investment.

Mr. Davison—The rate of interest depends greatly on the character of the security. We are not at present considering anything better than 5%.

Mr. Whited—I would like to ask if it is the idea to use all of the building for society purposes or to rent out part of it. That was my idea in organizing the stock company. I think we should try to make it a reasonably profitable investment, say 5 per cent.

Mr. T. H. Johnson—That question is one that we are hardly ready to answer yet. The committee has had under consideration in a general way three or four different schemes and outlines. One of these propositions is to purchase this property and continue to use it in its present form. There is also a proposition to go into it on a larger scale and raise by a stock company money enough to put up a larger building with surplus room, the rental of which would give us revenue to re-

duce our expenses. Those schemes are as yet too far in the air for the committee to venture to report on them. They are all under consideration.

Prof. Fessenden read the following communication from Mr. John A. Brashear:

ALLEGHENY, PA., Feb. 10, 1900.

To the President and Members of the Engineers' Society of Western Pennsylvania:

It is proposed to ask Congress during the present session for an appropriation to establssh a National Bureau for Standards and Standardization in the broadest sense, the functions of which shall be to preserve and distribute the general fundamental standards of length and mass; to also test all measuring instruments, mechanical, electrical, photometric, etc.; to test the strength of materials, to make experiments upon various alloys, etc.; in short, to undertake and carry out all these lines of testing and experimental investigations which are necessary for the development of the engineering and business interests of the country as a whole, and to establish uniform standards of test and testing that will be accepted without question by all parties.

It is hardly necessary to advance in detail the arguments in favor of such a bureau, for they will no doubt be self-evident to you and to every good engineer. All of the important foreign governments have established such bureaus and have liberally appropriated for their maintenance. They have fully demonstrated their usefulness therefore, practically as well as theoretically.

It is a national reproach that our own government has as yet done nothing in the way of adequately providing for such work.

The Bureau of Weights and Measures which has been for a number of years maintained in connection with the U. S. Coast and Geodetic Survey, has done good work in the comparison of bars, tapes, etc., but its very limited facilities have

proven utterly inadequate to satisfy the ever increasing demand for comparisons of this kind alone, although it has attempted to do all that it was possible to do. It is to be hoped that Congress will recognize the practical and immediate needs of expansion in this work, and take steps at once to provide for it ; and I hope you will be disposed to help the movement with your great personal influence. Those who contribute to its success will deserve and will in time receive the nation's gratitude.

(Signed) JOHN A. BRASHEAR.

MR. T. H. JOHNSON—I do not think any member of the engineering profession would for a moment question the benefits that would be derived from carrying sut such a scheme as is outlined in that letter, and as engineers I think we should do all we can to bring about such a result. Personally I do not look forward to any adequate results, at least for some years to come, for the reason that in order to make that bureau effective it must have the support of our congressmen. Unfortunately, our members of congress are not so wide awake to the needs of this as is this society, and the result will be that if the bureau could be established we might not be able to get an appropriation for current expenses. While I am heartily in favor of this I do not look for any practical results from it.

The society adopted the following resolution in regard to the communication received from Mr. Brashear:

Whereas, it is proposed to ask the present Congress for legislation to establish a National Bureau of Standards and Standardization, and

Whereas, such Bureau would be of the greatest value to the Scientific, Engineering, and business interests of this country, and particularly of this great engineering and industrial center,

Be It Resolved, that the Engineers' Society of Western Pennsylvania approve most heartily the establishment of such a Bureau, and we do hereby request the members of Congress

representing Western Pennsylvania to do all in their power toward the founding of such a Bureau.

Be It Further Resolved, that a copy of these resolutions be forwarded to our representatives in Congress.

Mr. C. B. Albree—I want to say that the American Society of Mechanical Engineers has issued a circular asking members all over the country, and local engineering societies to use their influence as far as possible in behalf of the United States Patent Office. As it is now, the Patent Office is a subdepartment of the Interior Department. If you have ever been in Washington you will have found that the Patent Office building is really devoted to the Interior Department and they have a great many other departments located in the building. The result is that the quarters for the practical work of the government are very much crowded, so much so that the halls are filled with cheap wooden cases containing drawings, and in case of fire nothing would prevent the loss of the original patents, and you know how valuable they are. The object is to get the government to procure the other departments a building somewhere else suitable for their needs and give the whole Patent Office building up for Patent Office purposes; and also have the government allow the income derived from the Patent Office to go to the benefit of the Patent Office. As it is now, anything over the actual expense goes into the general fund of the interior department. As a result, according to the circular, last year the funds available for the purchase of modern equipment, only amounted to $6,000. The American Society of Mechanical Engineers wants the local societies to confer with their congressmen and senators and urge them to have this thing attended to, and I move that this society communicate in the proper manner with our senators in regard to the matter. The circular I received asked that each member would interest himself enough to communicate with the congressmen personally or to write them.

Prof. Fessenden—As I understand it, the object is, first, that the Patent Office shall have the building to themselves, and second, they shall have their own income.

I would like to add some information; the total profits of the Patent Office amount to a trifle over five million dollars, and a great part of that has been spent in building a new Congressional Library.

Mr. Fisher—Would you have the committee appointed by the President? If so, it would be well to make a motion to that effect.

Mr. Albree—I think we should have a committee to formulate the thing. A committee of three would be sufficient to carry weight with it.

It was moved that a committee of three be appointed by the president of the society to formulate resolutions with reference to the Patent Office, at Washington, to the effect that the Patent Department be given the entire use of the present building and that the proceeds of the Patent Office be devoted exclusively to the Patent Office.

Mr. Albree—As I understand it, the patent office building is amply large enough for all the needs of the patent office, provided they could get the use of the building, but as it is now they have not got the use of anything like what they should have. This room and the surplus income should be devoted to the patent office purposes.

Mr. Fisher—The committee will have to decide some of those things. They can be brought up at some subsequent meeting. The object now is to have the committee appointed to look into the matter.

Mr. Albree—The matter comes up in the course of three weeks.

A Member—I think that if Mr. Albree would present that circular it would cover the ground as well as the society could wish. It would be a good thing for the committee to do what they are going to do as soon as possible.

MR. SCOTT—I move that this matter be placed in the hands of a committee, consisting of three members, to draw up resolutions, this committee having the power to add to its own number. They could then select such members of the society whose names might have weight with the members of Congress, and add as many as they deem desirable. In regard to the building, I was there some years ago, at the time Buffalo Bill had a tribe of Indians there, and they were in the building complaining to the Secretary of the Interior about their lands.

The motion as amended was that a committee of three be appointed and they have the power to select other influential members.

A MEMBER—If the committee is to do this within the next three weeks it will have to come up before the next meeting of the Society. There have been some mistakes made in the past by trying to hurry up matters of this kind.

MR. ALBREE—I think in this case there is not the danger that there is in matters which are simply technical. This is a matter in which we are all interested. Being associated more or less with manufacturers, it is greatly to the interest of the society that the patent office should be just as good as it can be. I think it lies within the discretion of the president to appoint a committee that it will be safe to trust in the matter.

MR. JOHNSON—The object and scope of the committee's action is pretty well defined. I don't think they can go far astray in that way. I would suggest that it would possibly be worth while to give the representative manufacturers a chance to sign the paper in their private capacity.

A MEMBER—I think that most of the leading manufacturers whose names would be desirable to attach to that, are members of this Society, but under the motion of Mr. Scott it would be under the discretion of the members of the committee to call on them.

Mr. Fisher—The motion before the house is that a committee of three be appointed who shall have the power to select influential members of the Society, to bring up the matter of having the facilities of the patent office enlarged, so there will be more room to conduct the business along the lines designated in the report of the American Society of Mechanical Engineers.

Motion carried.

The Vice President then appointed the following committee: Messrs. C. B. Albree, Julian Kennedy and Mr. C. A. Scott.

Next in order was the reading of the paper of the evening by Mr. Willis Whited, entitled "Reactions in Swing Bridge Trusses."

REACTIONS IN SWING-BRIDGE TRUSSES.

BY WILLIS WHITED.

In the present paper attention will be called to the pier and abutment reactions in trussed draw-bridges of both the center-bearing and rim-bearing types, *i. e.*, having either three or four points of support, with equal arms and acting as continuous girders.

The stresses in the various members will be touched upon only incidentally.

The stresses in continuous girders are usually calculated on the assumption that they are beams with uniform moment of inertia, and no account is taken of the deflections due to the web strains.

The author has designed a number of bridge trusses of various types and sizes and calculated the reactions in them in the usual manner, *i. e.*, by the theorem of three moments and also by the more accurate but far more laborious method of the principle of virtual velocities, and compared the results. The number of examples is not nearly so great as could be desired, but the results obtained are of much wider application than would appear at first sight.

The trusses were designed according to Cooper's specifications; although these give heavier posts than most others, little difficulty will be encountered on that score.

Truss No. 1 is a center-bearing pony truss, 150 feet long, divided into 10 panels 12 feet high. The dead load is assumed at 550 lbs. per foot, and the live load at 1,500 lbs. per foot per truss, with locomotive excesses as shown.

Truss No. 2 is of the same type and length as No. 1, except that it is divided into 12 panels 10 feet high, the loads being the same.

These two trusses were chosen in order to note the effects of different paneling. As it is only the reactions per unit of load we are studying, the assumed loading makes very little difference because the sections of all the members would be increased or diminished in nearly the same ratio as the loading. The reactions obtained, therefore, will be nearly the same per unit of load for a double-track bridge or for a highway or foot bridge as for the one designed. The same is true whatever the length of span, provided the form of the truss, the number of panels and the ratio of panel length to panel height are the same. Also, if the number of panels is increased the mean stress in the web members will be changed little, if at all, but their aggregate length will be increased, the deflections due to the strains in the web members will be increased, and the influence of that change on the reactions can be easily investigated as shown hereafter, and *vice versa*. Lastly, different specifications, if they increase or diminish all the unit stresses in the same ratio will make no difference, but a different impact formula or a different column formula might, in some cases, make so much difference as to require further investigation. These general remarks, of course, apply to all types of trusses.

Truss No. 3 is of the same type as No.'s 1 and 2, but it is 250 feet long and is divided into 10 panels 26 feet high, with loading as shown.

Truss No. 4 is of the same length, loading and panel length as No. 3, but it is 30 feet high.

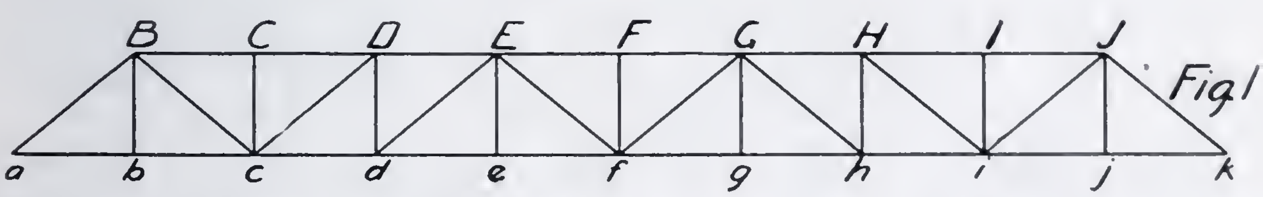
The two last were chosen for the purpose of studying the influence of length of span and height of truss.

No.'s 5, 7 and 8 are different forms of center-bearing trusses of the same length and loading as No.'s 3 and 4. No. 5 is occasionally met with, but No.'s 7 and 8 are seldom used. The last two were investigated more for the purpose of studying extreme cases than for any practical value they might have.

Truss No. 6 is the type used almost universally, with slight modifications, for rim-bearing turntables and merits more care-

ful study than perhaps any of the others. The stresses used in designing were calculated in the usual way, *i. e.*, ignoring the central panel and considering the truss as a continuous girder of two equal spans, *a f* and *f k* resting on three supports. It is supposed that the reason for calculating them in this manner is because no other logical method is generally known. The central panel can hardly be considered a third span on account of the lightness of the diagonals, which are made as small as is considered safe, or just about sufficient to prevent the bridge from collapsing when open, owing to unequal loading of the two arms or to a wind blowing lengthwise of the bridge. In fact they are sometimes omitted and the stiffness of the chords is relied upon to prevent collapse. Sometimes other devices are employed with the same end in view. There are serious objections to putting heavy diagonals in the central panel which we will not take time to discuss now.

A logical method, however, for determining the reactions, based on the theorem of three moments, omitting the central diagonals, will be found in *Engineering News* October 24, '95. The results obtained with this truss would, of course, have been somewhat different if the central panel had been longer or shorter.



No. 1. Swing Bridge. Center-bearing, 10 panels, 15′ long=150′ 12′ high.

Dead load=550 lbs. per ft. per truss=8,250 lbs. per panel per truss. Live load=1,500 lbs. per ft. per truss=22,500 lbs. per panel per truss, and two locomotive excesses of 10,000 lbs. each, three panels apart.

REACTIONS FOR 1 LB. PANEL LOAD BY THEOREM OF THREE MOMENTS.

	P_1	P_2	P_3	P_4
R_1	.752	.516	.304	.128
R_2	.296	.568	.792	.944
R_3	—.048	—.084	—.096	—.072

In the above table P_1=1 lb. load at *b*
R_1=Reaction at *a* P_2= " " " *c*
R_2= " " *f* P_3= " " " *d*
R_3= " " *k* P_4= " " " *e*

In the following table, *l*=length of member in feet. A=area of member in sq. in.

S_0=stress in member when truss is held at *f* and *k* only and 1 lb. load is at *a*. S_1=same with 1 lb. load at *b*. S_2= same with 1 lb. load at *c*. S_3=same with 1 lb. load at *d*. S_4= same with 1 lb. load at *e*.

	l	A	$\frac{1}{A}$	S_0	S_1	S_2	S_3	S_4	$\frac{l\ S_o}{A}$
BD	30.	15.25	1.967	2.5	1.25				4.918
DE	15.	15.25	.984	3.75	2.5	1.25			3.690
EF	15.	21.0	.714	6.25	5.0	3.75	2.5	1.25	4.463
ac	30.	11.24	2.669	1.25					3.336
cd	15.	15.18	.988	3.75	2.5	1.25			3.705
df	30.	18.18	1.650	5.0	3.75	2.5	1.25		8.250
aB	19.21	15.25	1.26	1.601					2.017
Bc	19.21	12.0	1.6	1.601	1.601				2.561
cD	19.21	9.2	2.088	1.601	1.601	1.601			3.343
Dd	12.	9.2	1.304	1.	1.	1.			1.304
dE	19.21	10 62	1.809	1.601	1.601	1.601	1.601		2.895
Ef	19.21	24.16	.795	1.601	1.601	1.601	1.601	1.601	1.273

Chords. Webs. Total.

$$\Sigma \frac{l\ S_0^2}{A} = 116.568 + 17.424 = 133.992$$

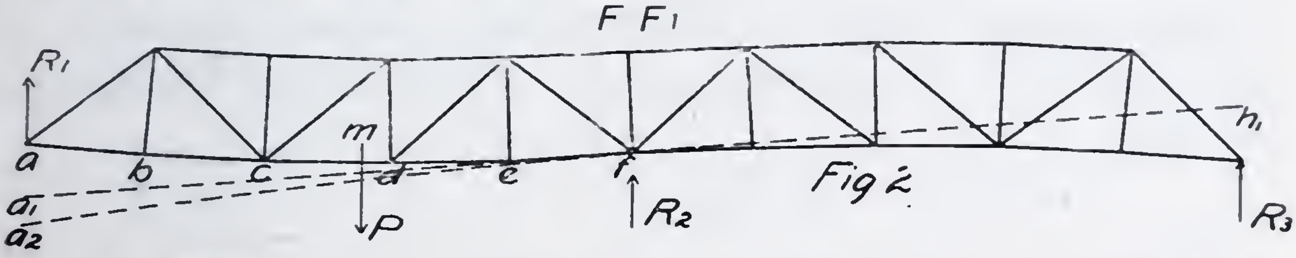
$$\Sigma \frac{l\ S_0 S_1}{A} = 77.888 + 17.424 = 95.312$$

$$\Sigma \frac{1\, S_0 S_2}{A} = 46.605 + 13.327 = 59.932$$

$$\Sigma \frac{1\, S_0 S_3}{A} = 21.470 + 6.671 = 28.141$$

$$\Sigma \frac{1\, S_0 S_4}{A} = 5.579 + 2.038 = 7.617$$

Each of the above algebraic expressions when multiplied by 12 and divided by E= about 29,000,000 gives the deflection of the truss at a produced by a load of 1 lb. at a b c d e respectively if it is unsupported at a and fixed at f so that the member Ff is held in a vertical position.



Let Fig. 2. represent any center-bearing truss with a load P at any panel-point m.

When the truss is supported at a. f. h. and loaded at b. c. d. or e. it is acted upon by the load P acting downward, the reactions R_1. R_2. acting upward and the reaction—R_3 acting downward and we have

$$P = R_2 + R_1 + R_3 \tag{1}$$

and as the sum of the moments must = o and considering that P acts at panel point m

$$P \times fm = fa \times R_1 - fh \times R_3 \tag{2}$$

Draw a_1 h_1 perpendicular to Ff. The load P deflects a from a_1 to a_2. Reaction R_1 deflects it from a_2 to a. Reaction R_3 deflects h from h_1 to h or

Deflection due to R_1=deflection due to P+deflection due to R_3

$$\text{Deflection due to } R_1 = \frac{12 R_1}{E} \Sigma \frac{1 S_0^2}{A}$$

$$\text{Deflection due to } R_3 = \frac{12\ R_3}{E} \Sigma \frac{1 S_0^2}{A}$$

$$\text{Deflection due to } P = \frac{12\ P}{E} \Sigma \frac{1 S_0 Sm}{A}$$

$$\text{whence } R_1 \lesseqgtr \frac{1 S_0^2}{A} = R_3 \lesseqgtr \frac{1 S_0^2}{A} + P \lesseqgtr \frac{1 S_0 Sm}{A} \qquad (3)$$

From equations (1) (2) (3) R_1 R_2 R_3 can be determined. Applying them to truss No. 1 we have

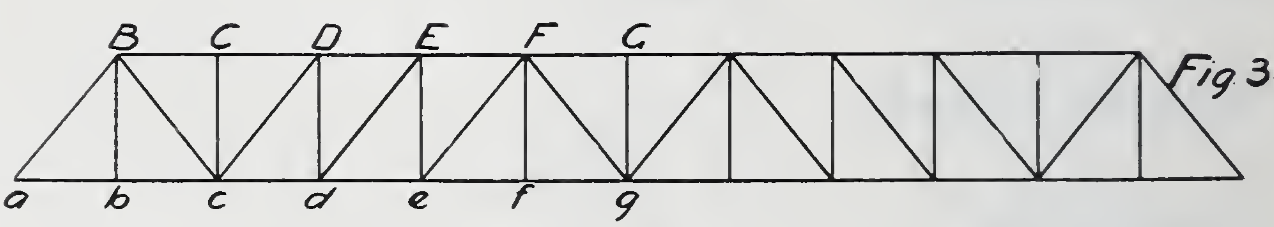
	P_1	P_2	P_3	P_4
R_1	.756	.524	.305	.128
R_2	.288	.552	.790	.944
R_3	—.044	—.076	—.095	—.072

Cooper's specifications call for heavier compression members than some others, so, in order to see roughly the effect of lighter compression members, the author increased the principal tension members E F. *a c.* *d* E each 20%, which is the same as reducing all of the other members $16\frac{2}{3}$%, with the following results:

	Chords.	Webs.	
$\lesseqgtr \frac{1 S_0^2}{A} =$	122.981	+18.351	=141.332
$\lesseqgtr \frac{1 S_0 S_1}{A} =$	82.351	+18.351	=100.702
$\lesseqgtr \frac{1 S_0 S_2}{A} =$	49.952	+14.254	= 64.206
$\lesseqgtr \frac{1 S_0 S_3}{A} =$	23.701	+ 7.598	= 31.299
$\lesseqgtr \frac{1 S_0 S_4}{A} =$	6.695	+ 2.038	= 8.733

	P_1	P_2	P_3	P_4
R_1	.756	.527	.311	.131
R_2	.288	.546	.778	.938
R_3	—.044	—.073	—.089	—.069

TRUSS No. 2.



Center-bearing Swing Bridge, 12 panels 12′ 6″ each=150′, 10′ deep.

Dead load = 560 pounds per foot per truss = 7,000 pounds per panel per truss.

Live load = 1,520 pounds per foot per truss = 19,000 pounds per panel per truss with two excesses of 10,000 pounds 3 panels apart.

REACTIONS FOR ONE POUND PANEL LOAD BY THEOREM OF THREE MOMENTS.

	P_1	P_2	P_3	P_4	P_5
R_1	.7928	.5926	.40625	.24075	.103
R_2	.2477	.4815	.6875	.85185	.9607
R_3	—.0405	—.0741	—.09375	—.0926	—.0637

The notation is similar to that employed under truss No. 1.

	l	A	$\frac{l}{A}$	S_0	S_1	S_2	S_3	S_4	S_5	$\frac{l\ S_0}{A}$
BD	25.	15.72	1.59	2.5	1.25					3.975
DE	12.5	15.72	.795	3.75	2.5	1.25				2.981
EF	12.5	18.72	.668	5.0	3.75	2.5	1.25			3.340
FG	12.5	30.	.417	7.5	6.25	5.0	3.75	2.5	1.25	3.125
ac	25.	11.76	1.063	1.25						1.329
cd	12.5	17.76	.704	3.75	2.5	1.25				2.640
de	12.5	17.76	.704	5.0	3.75	2.5	1.25			3.520
eg	25.	22.58	1.107	6.25	5.0	3.75	2.5	1.25		6.919
aB	16.	15.72	1.018	1.6						1.629
Bc	16.	12.0	1.333	1.6	1.6					2 133
cD	16.	15.	1.067	1.6	1.6	1.6				1.707
Dd	10.	9.	1.111	1.	1.	1.				1.111
dE	16.	12.	1.333	1.6	1.6	1.6	1.6			2.133
Ee	10.	9.	1.111	1.	1.	1.	1.			1.111
eF	16.	11.88	1.347	1.6	1.6	1.6	1.6	1.6		2.155
Fg	16.	23.2	.69	1.6	1.6	1.6	1.6	1.6	1.6	1.104

Chords. Webs.

$$\lessgtr \frac{l\,S_0^2}{A} = 133.659 + 19.384 = 153.043$$

$$\lessgtr \frac{l\,S_0 S_1}{A} = 98.873 + 16.778 = 115.651$$

$$\lessgtr \frac{l\,S_0 S_2}{A} = 65.747 + 13.365 = 79.112$$

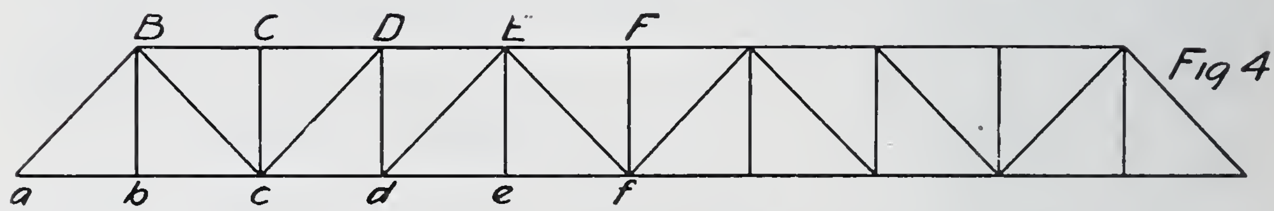
$$\Sigma\frac{1\,S_0S_3}{A} = 37.592 + 9.523 = 47.115$$

$$\Sigma\frac{1\,S_0S_4}{A} = 16.462 + 4.999 = 21.461$$

$$\Sigma\frac{1\,S_0S_5}{A} = 3.906 + 1.766 = 5.672$$

	P_1	P_2	P_3	P_4	P_5
R_1	.795	.592	.404	.237	.102
R_2	.244	.483	.692	.860	.963
R_3	—.039	—.075	—.096	—.097	—.065

TRUSS No. 3.



Center-bearing Swing Bridge, 10 panels @ 25′ = 250′, 26′ high.

Dead load = 800 pounds per foot per truss, = 20,000 pounds per panel per truss.

Live load = 1,500 pounds per foot per truss, = 37,500 pounds per panel per truss, with two locomotive excesses of 10,000 pounds each, two panels apart.

	l	A	$\frac{1}{A}$	S_0	S_1	S_2	S_3	S_4	$\frac{1\,So}{A}$
BD	50.	20.44	2.446	1.923	.961				4.703
DE	25.	21.68	1.153	2.884	1.923	.961			3.324
EF	25.	32.38	.772	4.807	3.846	2.884	1.923	.961	3.711
ac	50.	14.51	3.446	.961					3.311
cd	25.	20.69	1.208	2.884	1.923	.961			3 484
df	50.	28.5	1.754	3.846	2.884	1.923	.961		6.745
aB	36.069	20.44	1.765	1.387					2.448
Bc	36.069	19.7	1.831	1.387	1.387				2.539
cD	36.069	18.94	1.904	1.387	1.387	1.387			2.640
Dd	26.	17.7	1.469	1.	1.	1.			1.469
dE	36.069	18.38	1.962	1.387	1 387	1.387	1.387		2.721
Ef	36.069	44.5	.811	1.387	1.387	1.387	1.387	1.387	1.125

Chords. Webs.

$$\Sigma \frac{1 S_0^2}{A} = 75.609 + 17.381 = 92.990$$

$$\Sigma \frac{1 S_0 S_1}{A} = 51.317 + 13.987 = 65.304$$

$$\Sigma \frac{1 S_0 S_2}{A} = 30.207 + 10.465 = 40.672$$

$$\Sigma \frac{1 S_0 S_3}{A} = 13.616 + 5.335 = 18.951$$

$$\Sigma \frac{1 S_0 S_4}{A} = 3.567 + 1.561 = 5.128$$

	P_1	P_2	P_3	P_4
R_1	.751	.518	.302	.128
R_2	.298	.564	.796	.944
R_3	—.049	—.082	—.098	—.072

TRUSS No. 4.

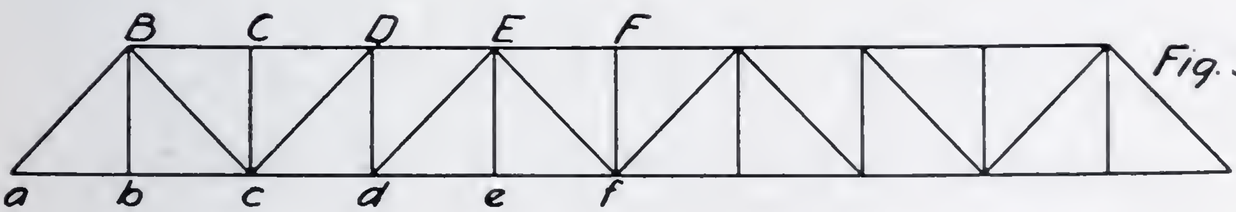


Fig. 5

Same as No. 3, except 30 feet high. Same loading.

	1	A	$\frac{1}{A}$	S_0	S_1	S_2	S_3	S_4	$\frac{1 S_0}{A}$
BD	50.	20.22	2.473	1.667	.833				4.122
DE	25.	20.22	1.236	2.5	1.667	.833			3.090
EF	25.	28.52	.88	4.167	3.333	2 5	1.667	.833	3.667
ac	50.	15.14	3.302	.833					2.752
cd	25.	16.46	1.519	2.5	1.667	.833			3.798
df	50.	23.44	2.133	3.333	2.5	1.667	.833		7.110
aB	39.051	21.98	1.777	1.302					2.313
Bc	39.051	22.	1.775	1.302	1.302				2.311
cD	39.051	25.	1.562	1.302	1.302	1.302			2.034
Dd	30.	21.02	1.471	1.	1.	1.			1.471
dE	39.051	17.5	2.231	1.302	1.302	1.302	1.302		2.905
Ef	39.051	53.	.737	1.302	1.302	1.302	1.302	1.302	.959

Chords. Webs.

$$\Sigma \frac{l S_0^2}{A} = 65.363 + 15.172 = 80.535$$

$$\Sigma \frac{l S_0 S_1}{A} = 44.914 + 12.160 = 57.074$$

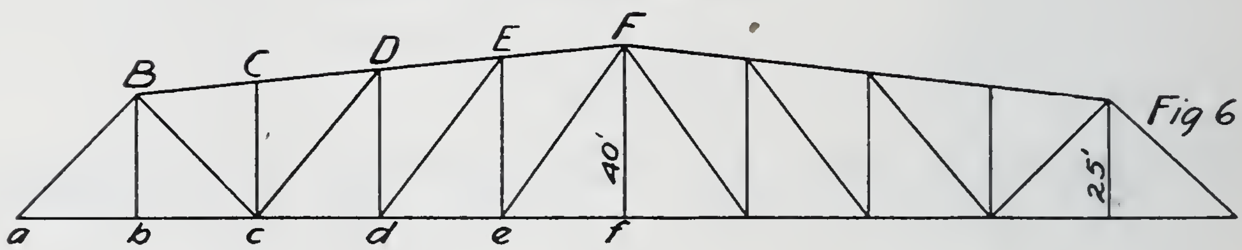
$$\Sigma \frac{l S_0 S_2}{A} = 26.758 + 9.151 = 35.909$$

$$\Sigma \frac{l S_0 S_3}{A} = 12.037 + 5.032 = 17.069$$

$$\Sigma \frac{l S_0 S_4}{A} = 3.056 + 1.249 = 4.305$$

	P_1	P_2	P_3	P_4
R_1	.754	.523	.306	.127
R_2	.292	.554	.788	.946
R_3	—.046	—.077	—.094	—.073

TRUSS No. 5.



Center-bearing Swing Bridge. 10 panels @ 25 ft.=250′.
Loading same as No. 3.

	l	A	$\frac{l}{A}$	S_0	S_1	S_2	S_3	S_4	$\frac{l\ S_0}{A}$
BD	50.56	19.84	2.545	1.758	.879				4.474
DE	25.28	19.84	1.272	2.333	1.555	.777			2.968
EF	25.28	13.5	1.873	2.788	2.091	1.394	.697		5.222
ac	50.	17.73	2.820	1.					2.820
cd	25.	17.73	1.410	2.307	1.538	.769			3.253
de	25.	22.23	1.125	2.759	2.069	1.379	.689		3.104
ef	25.	32.12	.778	3.125	2 500	1.875	1.250	.625	2.431
aB	35.35	23.48	1.506	1.414					2.129
Bc	35.35	28.	1.263	1.045	1.229				1.319
cD	41.	12.75	3.215	.932	1.095	1.262			2.997
Dd	32.5	17.58	1.849	.656	.77	.884			1.212
dE	44.03	15.75	2.795	.797	.935	1.074	1.215		2.228
Ee	36.25	26.48	1.369	.586	.69	.794	.898		.802
eF	47.17	20.	2.354	.69	.813	.935	1.058	1.179	1.624
Ff	40.	65.34	.612	1.	1.	1.	1.	1.	.612

Chords. Webs.

$$\Sigma \frac{l S_0^2}{A} = 55.833 + 11.954 = 67.787$$

$$\Sigma \frac{l S_0 S_1}{A} = 36.969 + 10.404 = 47.373$$

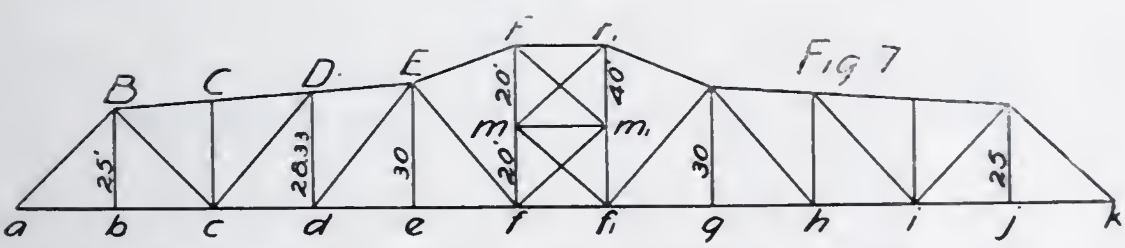
$$\Sigma \frac{l S_0 S_2}{A} = 20.923 + 10.014 = 30.937$$

$$\Sigma \frac{l S_0 S_3}{A} = 8.816 + 5.757 = 14.573$$

$$\Sigma \frac{l S_0 S_4}{A} = 1.520 + 2.525 = 4.045$$

	P_1	P_2	P_3	P_4
R_1	.749	.528	.307	.130
R_2	.302	.544	.786	.940
R_3	—.051	—.072	—.093	—.070

TRUSS No. 6.



<—Five 23′ panels = 115′—>21<—Five 23′ panels = 115′—>

<——————250′——————>

Rim-bearing Swing Bridge.

Dead load = 800 pounds per ft. per truss = 18,400 pounds per panel per truss.

Live load = 1,500 pounds per foot per truss = 34,500 pounds per panel per truss.

Two locomotive excesses of 10,000 lbs., two panels apart.

Reactions for 1 lb. panel load by formula in Eng. News, October 24, 1895, which is $R_4 = \frac{P(l_1^2 - Z^2)Z}{2 l_1 l_3 (l_1 + 3 l_2 + l_3)}$ in which

	P_1	P_2	P_3	P_4
R_1	.762	.533	.324	.143
R_2	.238	.467	.676	.857
R_3	+.038	+.067	+.076	+.057
R_4	—.038	—.067	—.076	—.057

$l_1 = af$ $l_3 = f_1 k$
$l_2 = ff_1$
Z = distance from a to loaded point.

TRUSS No. 6 FIXED AT *Ff*.

	l	A	$\frac{l}{A}$	S_0	S_1	S_2	S_3	S_4	$\frac{l\ S_0}{A}$
BD	46.12	20.22	2.28	1.73	.865				3.944
DE	23.06	20.22	1.140	2.442	1.628	.814			2.784
EF	25 08	19.25	1.303	3.133	2.508	1.88	1.254	.626	4.082
ac	46.	14.08	3.267	.92					3.005
cd	23.	20.26	1.135	2.435	1.624	.812			2.764
df	46.	20.26	2.27	3.067	2.3	1.533	.767		6.961
aB	33.97	20.22	1.68	1.359					2.283
Bc	33.97	19.14	1.775	1.189	1.274				2.110
cD	36.49	15.94	2.289	1.127	1.207	1.289			2 579
dD	28.33	14.08	2.012	.824	.884	.94			1.658
dE	37.8	14.25	2.653	1.039	1.111	1.186	1.260		2.756
Ef	37.8	26.5	1.426	.315	0.	-.318	- 629	-.945	.449
Ff	40.	13.08	3.058	1.25	1.	.75	.5	.25	3.823

When center diagonals are omitted, truss fixed at F_1 f_1 and f members between a and f same as above.

FF_1	20.	18.38	1.088	2.875	2.3	1.725	1.15	.575	3.128
ff_1	20.	22.44	.891	2.875	2.3	1.725	1.15	.575	2.562

TRUSS No. 6 FIXED AT $F_1 f_1$, NO STRESS IN mF_1 AND fm_1.

	l	A	$\frac{l}{A}$	S_0	S_1	S_2	S_3	S_4	S_5	$\frac{l S_0}{A}$	$\frac{l S_5}{A}$
BD	46.12	20.22	2.28	1.73	.865					3.944	
DE	23.06	20.22	1.140	2.442	1.628	.814				2.784	
EF	25.08	19.25	1.303	3.133	2.508	1.88	1.254	.626		4.082	
FF_1	20.	18.38	1.088	3.375	2.8	2.225	1.65	1.075	.5	3.671	.544
ac	46.	14.08	3.267	.92						3.005	
cd	23.	20.26	1.135	2.435	1.624	.812				2.764	
df	46.	20.26	2.27	3.067	2 3	1.533	.767			6.961	
ff_1	20.	22 44	.891	2.875	2 3	1.725	1.15	.575		2.561	
aB	33.97	20.22	1.68	1.359						2.283	
Bc	33.97	19.14	1.775	1 189	1.274					2.110	
cD	36.49	15.94	2.289	1.127	1 207	1.289				2.579	
dD	28.33	14.08	2.012	.824	.884	.94				1.658	
dE	37.8	14.25	2.653	1 039	1.111	1.186	1.260			2.756	
Ef	37.8	26.5	1.426	.315	.0	- .318	- .629	- .945		.449	
Fm	20.	13.08	1.529	.75	.5	.25	.0	- .25	-.5	1.147	- .765
mf	20.	13.08	1.529	.25	.0	- .25	- .5	- .75	-1.0	.382	-1.529
m_1f_1	20.	13.08	1.529	.5	.5	.5	.5	.5	.5	.765	.765
Fm_1	28.28	1.56	18.1	.707	.707	.707	.707	.707	.707	12.797	12.797
mm_1	20.	4.76	4.202	.5	.5	.5	.5	.5	.5	2.101	2.101
mf_1	28.28	1.56	18.1	.707	.707	.707	.707	.707	.707	12.797	12.797

Truss fixed at $F. f.$

	Chords.		Webs.		Total.
$\Sigma \frac{l S_0^2}{A} =$	57.255	+	17.668	=	74.923
$\Sigma \frac{l S_0 S_1}{A} =$	38.674	+	14.152	=	52.826
$\Sigma \frac{l S_0 S_2}{A} =$	22.856	+	10.876	=	33.732
$\Sigma \frac{l S_0 S_3}{A} =$	10.453	+	5.103	=	15.556
$\Sigma \frac{S_0 S_4}{A} =$	2.558	+	.532	=	3.090

Center panel omitted.

	P_1	P_2	P_3	P_4
R_1	+.752	+.525	+.304	+.120
R_2	+.295	+.550	+.792	+.959
R_3	—.047	—.075	—.096	—.079

Truss fixed at $F_1 f_1$ and f, center diagonals omitted.

Chords. Webs. Total.

$$\lessgtr \frac{l\,S_0^2}{A} = 73.615+17.668=91.283$$

$$\lessgtr \frac{l\,S_0S_1}{A} = 51.762+14.152=65.914$$

$$\lessgtr \frac{l\,S_0S_2}{A} = 32.672+10.876=43.548$$

$$\lessgtr \frac{l\,S_0S_3}{A} = 16.997+\ 5.103=22.100$$

$$\lessgtr \frac{l\,S_0S_4}{A} = 5.830+\ .532=\ 6.362$$

	P_1	P_2	P_3	P_4
R_1	+.757	+.532	+.313	+.128
R_2	+.243	+.468	+.687	+.872
R_3	+.043	+.068	+.087	+.072
R_4	—.043	—.068	—.087	—.072

TRUSS FIXED AT $F_1 f_1$.

Chords. Webs.

$$\lessgtr \frac{l\,S_0^2}{A} = 77.008+33.373=110.381$$

$$\lessgtr \frac{l\,S_0S_1}{A} = 54.850+30.432=\ 85.282$$

$$\lessgtr \frac{l\,S_0S_2}{A} = 35.441+27.729=\ 63.170$$

$$\lessgtr \frac{l\,S_0S_3}{A} = 19.460+22.529=\ 41.989$$

$$\lessgtr \frac{l\,S_0S_4}{A} = 7.974+18.531=\ 26.505$$

$$\lessgtr \frac{l\,S_0S_5}{A} = 1.836+18.573=\ 20.409$$

$$\lessgtr \frac{l\,S_1S_5}{A} = 20.669$$

$$\lessgtr \frac{l\,S_2S_5}{A} = 20.931$$

$$\lessgtr \frac{l\,S_3S_5}{A} = 21.192$$

$$\lessgtr \frac{l\,S_4S_5}{A} = 21.452$$

$$\lessgtr \frac{l\,S_5^2}{A} = 21.712$$

Truss fixed as above, center diag's and strut doubled.

Chords. Webs.

$$\Sigma \frac{l\,S_0^{\,2}}{A} = 77.008 + 23.800 = 100.808$$

$$\Sigma \frac{l\,S_0S_1}{A} = 54.850 + 20.859 = 75.709 \qquad \Sigma \frac{l\,S_1S_5}{A} = 11.096$$

$$\Sigma \frac{l\,S_0S_2}{A} = 35.441 + 18.156 = 53.597 \qquad \Sigma \frac{l\,S_2S_5}{A} = 11.358$$

$$\Sigma \frac{l\,S_0S_3}{A} = 19.460 + 12.956 = 32.416 \qquad \Sigma \frac{l\,S_3S_5}{A} = 11.619$$

$$\Sigma \frac{l\,S_0S_4}{A} = 7.974 + 8.958 = 16.932 \qquad \Sigma \frac{l\,S_4S_5}{A} = 11.879$$

$$\Sigma \frac{l\,S_0S_5}{A} = 1.836 + 9.000 = 10.836 \qquad \Sigma \frac{l\,S_5^{\,2}}{A} = 12.139$$

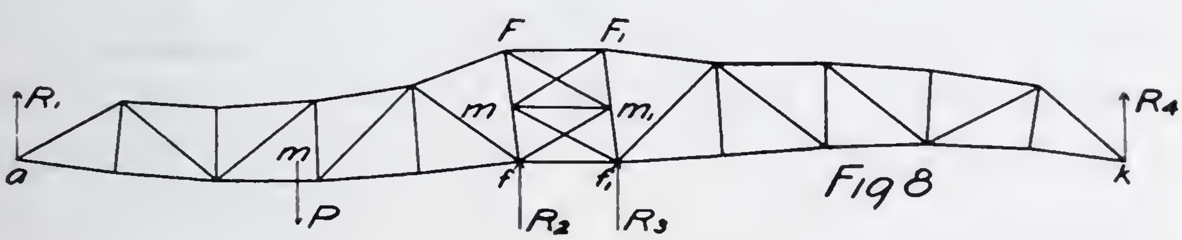


Fig 8

By reference to Fig. 8, by a method similar to that under Fig. 2, the following equations can readily be deduced:

$$\frac{\text{Deflection of } a\,f_1 \text{ due to } R_2}{a\ f_1} + \frac{\text{Deflection } a\,f_1 \text{ due to } R_1}{a\ f_1} - \frac{\text{Deflection } a\ f_1 \text{ due to } P}{a\ f_1} = -\frac{\text{Deflection } f_1\ k \text{ due to } R_4}{f_1\ k} \qquad (4)$$

also

$$\frac{\text{Deflection } f\,f_1 \text{ due to } R_2}{f\ f_1} + \frac{\text{Deflection } f\,f_1 \text{ due to } R_1}{f\ f_1} - \frac{\text{Deflection } f\ f_1 \text{ due to } P}{f\ f_1} = -\frac{\text{Deflection } f_1\ k \text{ due to } R_4}{f_1\ k} \qquad (5)$$

also $R_1 + R_2 + R_3 + R_4 = P$ (6)

and $R_1 \times a\,f_1 + R_2 \times f\,f_1 - R_4 \times f_1\,k = P \times m\ f_1$ (7)

Substituting the deflections as obtained above in equations (4) (5) (6) (7) we obtain the following equations, remembering that there is no stress in $m\ F_1$ nor in $f\ m_1$:

No. 6 TRUSS AS DESIGNED.

Load at *b*.

$$-\frac{85.282}{135}+\frac{110.381}{135}R_1+\frac{20.409}{135}R_2=-\frac{74.923}{115}R_4 \qquad R_1= \ .756$$

$$-\frac{20.669}{20}+\frac{20.409}{20}R_1+\frac{21.712}{20}R_2=-\frac{74.923}{115}R_4 \qquad R_2= \ .266$$

$$135R_1+20R_2-115R_4=112 \qquad R_3= \ .019$$

$$R_1+R_2+R_3+R_4=1 \qquad R_4=-.041$$

Load at *c*.

$$-\frac{63.170}{135}+\frac{110.381}{135}R_1+\frac{20.409}{135}R_2=-\frac{74.923}{115}R_4 \qquad R_1= \ .530$$

$$-\frac{20.931}{20}+\frac{20.409}{20}R_1+\frac{21.712}{20}R_2=-\frac{74.923}{115}R_4 \qquad R_2= \ .504$$

$$135R_1+20R_2-115R_4=89 \qquad R_3= \ .030$$

$$R_1+R_2+R_3+R_4=1 \qquad R_4=-.064$$

Load at *d*.

$$-\frac{41.989}{135}+\frac{110.381}{135}R_1+\frac{20.409}{135}R_2=-\frac{74.923}{115}R_4 \qquad R_1= \ .310$$

$$-\frac{21.192}{20}+\frac{20.409}{20}R_1+\frac{21.712}{20}R_2=-\frac{74.923}{115}R_4 \qquad R_2= \ .734$$

$$135R_1+20R_2-115R_4=66 \qquad R_3= \ .038$$

$$R_1+R_2+R_3+R_4=1 \qquad R_4=-.082$$

Load at *e*.

$$-\frac{26.505}{135}+\frac{110.381}{135}R_1+\frac{20.409}{135}R_2=-\frac{74.923}{115}R_4 \qquad R_1= \ .126$$

$$-\frac{21.452}{20}+\frac{20.409}{20}R_1+\frac{21.712}{20}R_2=-\frac{74.923}{115}R_4 \qquad R_2= \ .910$$

$$135R_1+20R_2-115R_4=43 \qquad R_3= \ .032$$

$$R_1+R_2+R_3+R_4=1 \qquad R_4=-.068$$

No. 6 TRUSS CENTER WEB MEMBERS DOUBLED.

Load at *b*.

$$-\frac{75.709}{135}+\frac{100.808}{135}R_1+\frac{10.836}{135}R_2=-\frac{74.923}{115}R_4 \qquad R_1=.755$$

$$-\frac{11.096}{20}+\frac{10.836}{20}R_1+\frac{12.139}{20}R_2=-\frac{74.923}{115}R_4 \qquad R_2=.282$$

$$135R_1+20R_2-115R_4=112 \qquad R_3=.002$$

$$R_1+R_2+R_3+R_4=1 \qquad R_4=-.039$$

Load at *c*.

$$-\frac{53.597}{135}+\frac{100.808}{135}R_1+\frac{10.836}{135}R_2=-\frac{74.923}{115}R_4 \qquad R_1=.528$$

$$-\frac{11.358}{20}+\frac{10.836}{20}R_1+\frac{12.139}{20}R_2=-\frac{74.923}{115}R_4 \qquad R_2=.530$$

$$135R_1+20R_2-115R_4=89 \qquad R_3=.003$$

$$R_1+R_2+R_3+R_4=1 \qquad R_4=-.061$$

Load at *d*.

$$-\frac{32.416}{135}+\frac{100.808}{135}R_1+\frac{10.836}{135}R_2=-\frac{74.923}{115}R_4 \qquad R_1=.308$$

$$-\frac{11.619}{20}+\frac{10.836}{20}R_1+\frac{12.139}{20}R_2=-\frac{74.923}{115}R_4 \qquad R_2=.767$$

$$135R_1+20R_2-115R_4=66 \qquad R_3=.004$$

$$R_1+R_2+R_3+R_4=1 \qquad R_4=-.079$$

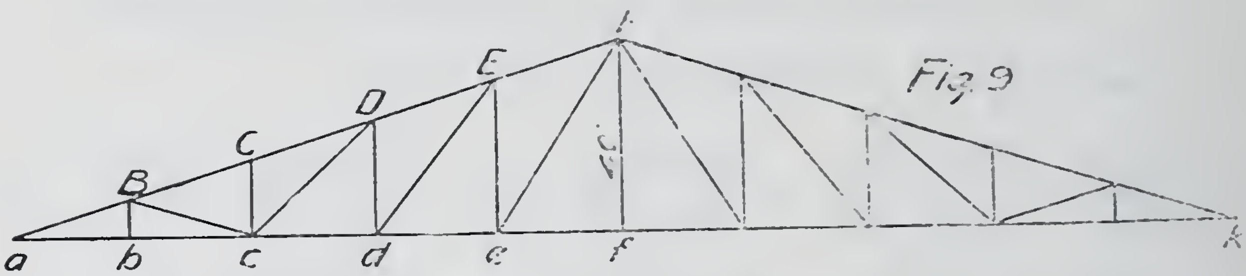
Load at *e*

$$-\frac{16.932}{135}+\frac{100.808}{135}R_1+\frac{10.836}{135}R_2=-\frac{74.923}{115}R_4 \qquad R_1=.124$$

$$-\frac{11.879}{20}+\frac{10.836}{20}R_1+\frac{12.139}{20}R_2=-\frac{74.923}{115}R_4 \qquad R_2=.938$$

$$135R_1+20R_2-115R_4=43 \qquad R_3=.003$$

$$R_1+R_2+R_3+R_4=1 \qquad R_4=-.065$$



Center-bearing Swing Bridge, 10 panels @ 25′ = 250′.

Dead load = 800 pounds per ft. per truss = 20,000 pounds per panel per truss. Live load = 1,500 pounds per foot per truss = 37,500 pounds per panel per truss, and two locomotive excesses of 10,000 pounds, two panels apart.

	l	A	$\frac{l}{A}$	S_0	S_1	S_2	S_3	S_4	$\frac{l S_0}{A}$
aB	26.25	47.44	.553	3.281					1.815
BD	52.5	35.4	1.483	3.281	1.641				4.865
DE	26.25	28.54	.92	3.281	2.187	1.094			3.019
EF	26.25	28.54	.92	3.281	2.461	1.641	.820		3.019
ac	50.	41.	1.219	3.125					3.809
cd	25.	21.91	1.141	3.125	2 083	1.042			3.566
de	25.	21.91	1.141	3.125	2.344	1.563	.781		3.566
ef	25.	'25.92	.965	3.125	2.500	1.875	1.25	.625	3.016
Bc	26 25	18.58	1.413		1.641				
cD	34.66	13.5	2.567		.721	1.443			
Dd	24.	11.8	2.034		.334	.667			
dE	40.61	15.75	2.578		.422	.846	1.269		
Ee	32.	18.8	1.702		.250	.5	.75		
eF	47.17	17.5	2.695		.294	.589	.884	1.179	
Ff	40.	59.98	.667	1.0	1.0	1.0	1.0	1.0	.667

REACTIONS FOR 1 POUND PANEL LOAD BY THEOREM OF THREE MOMENTS.

	P_1	P_2	P_3	P_4
R_1	.752	.516	.304	.128
R_2	.296	.568	.792	.944
R_3	—.048	—.084	—.096	—.072

Chords. Webs. Total.

$$\lessgtr \frac{l S_0^2}{A} = 85.341 + .667 = 86.008$$

$$\lessgtr \frac{l S_0 S_1}{A} = 45.341 + .667 = 46.008$$

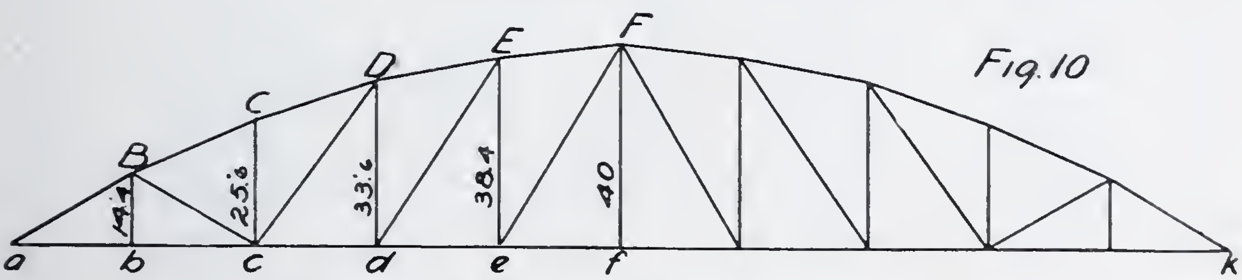
$$\Sigma \frac{l\,S_0S_2}{A} = 23.198 + .667 = 23.865$$

$$\Sigma \frac{l\,S_0S_3}{A} = 9.028 + .667 = 9.695$$

$$\Sigma \frac{l\,S_0S_4}{A} = 1.884 + .667 = 2.551$$

Reactions.

	P_1	P_2	P_3	P_4
R_1	.667	.439	.256	.115
R_2	.466	.722	.888	.970
R_3	—.133	—.161	—.144	—.085



Center-bearing Swing Bridge, 10 panels @ 25′ = 250′.

Dead load = 800 pounds per foot per truss = 20,000 pounds per panel per truss.

Live load = 1,500 pounds per foot per truss = 37,500 pounds per panel per truss, with two excesses of 10,000 pounds each two panels apart.

	l	A	$\frac{l}{A}$	S_0	S_1	S_2	S_3	S_4	$\frac{l\,S_0}{A}$
aB	28.85	29.79	.968	2.004					1.940
BC	27.39	26.91	1.018	2.140	1.07				2.178
CD	26.25	26.91	.975	2.051	1.025				2.000
DE	25.46	26.91	.946	2.273	1.515	.758			2.150
EF	25.05	26.91	.931	2.610	1.957	1.305	.652		2.429
ac	50.	22.	2.273	1.736					3.945
cd	25.	16.24	1.539	2.232	1.488	.744			3.435
de	25.	17.62	1.419	2.604	1.953	1.302	.651		3.695
ef	25.	28.	.893	3.125	2.5	1.875	1.25	.625	2.790
Bc	28.85	17.64	1.635	.251	1.127				.410
Cc	25.6	8.82	2.902	.249	.126				.722
cD	41.88	12.	3.490	.466	.856	1.247			1.626
Dd	33.6	16.46	2.041	.571	.714	.857			1.166
dE	45.82	15.75	2.909	.682	.852	1.022	1.193		1.984
Ee	38.4	27.2	1.412	.832	.875	.917	.959		1.175
eF	47.17	22.	2.144	.983	1.032	1.08	1.130	1.179	2.107
Ff	40.	37.	1.081	1.	1.	1.	1.	1.	1.081

	Chords.		Webs.		Totals.
$\Sigma \frac{1\ S_0^2}{A}$ =	56.732	+	7.187	=	63.920
$\Sigma \frac{1\ S_0 S_1}{A}$ =	31.692	+	8.748	=	40.440
$\Sigma \frac{1\ S_0 S_2}{A}$ =	17.398	+	9.487	=	26.885
$\Sigma \frac{1\ S_0 S_3}{A}$ =	7.476	+	6.954	=	14.430
$\Sigma \frac{1\ S_0 S_4}{A}$ =	1.744	+	3.565	=	5.309

Reactions.

	P_1	P_2	P_3	P_4
R_1	.716	.510	.313	.142
R_2	.368	.580	.774	.916
R_3	—.084	—.090	—.087	—.058

STRESSES IN TRUSS NO. 1 BY THEOREM OF THREE MOMENTS COMPARED WITH CORRECT STRESSES.

	Maximum Stresses by Theorem of Three Moments.	Correct Stresses.	Errors %	Minimum Stresses by Theorem of Three Moments.	Correct Stresses.	Errors %
BD	+ 98,960	+100,440	− 1.46	− 50,810	− 49,980	+ 1.66
DE	+ 82,840	+ 84,780	− 2.3	− 91,690	− 90,440	+ 1.38
EF				−249,560	−245,840	+ 1.51
ac	+ 20,250	+ 19,830	+ 2.09	− 73,250	− 73,920	− .91
cd	+ 91,690	+ 90,440	+ 1.38	− 82,840	− 84,780	− 2.3
df	+142,880	+141,210	+ 1.17			
aB	+ 93,800	+ 94,670	− .93	− 25,930	− 25,400	+ 2.09
Bc	+ 48,070	+ 47,920	+ .31	− 47,690	− 48,480	− 1.62
cD	+ 11,510	+ 12,890	−10.73	− 78,700	− 78,290	+ .52
dD	+ 49,170	+ 48,920	+ .52	− 7,810	− 8,050	− 3.01
dE				−116,960	−116,520	+ .38
Ef	+166,840	+166,280	+ .33			

TRUSS NO. 6. STRESSES BY THEOREM OF THREE MOMENTS COMPARED WITH CORRECT STRESSES.

	Maximum Stresses by Theorem of Three Moments.	Correct Stresses.	Error %	Minimum Stresses by Theorem of Three Moments.	Correct Stresses.	Error %
BD	+111,410	+115,070	− 3.18	− 68,360	− 65,260	+ 4.75
DE	+ 86,440	+ 89,710	− 3.64	−118,940	−114,570	+ 3.81
EF				−242,790	−233,490	+ 3.98
FF_1				−222,670	−214,150	+ 3.98
ac	+ 27,890	+ 26,240	+ 6.29	− 87,360	− 89,300	− 2.18
cd	+118,630	+115,490	+ 2.72	− 86,080	− 91,310	− 5.72
df	+177,600	+172,110	+ 3.19	− 20,000	− 26,470	−24.43
aB	+129,240	+131,920	− 2.03	− 41,180	− 38,750	+ 6.26
Bc	+ 72,610	+ 74,030	− 1.92	− 53,690	− 56,080	− 4.27
cD	+ 3,310	+ 4,950	−33.12	−116,890	−121,100	− 3.47
dD	+ 85,440	+ 88,460	− 3.42	− 2,450	− 3.640	−32.60
dE				−163,320	+173,220	− 5.72
Ef	+141,330	+142,000	− .47			
Ff	+ 96,830	+ 93,790	+ 3.25			
ff_1	+222,670	+214,150	+ 3.98			

TRUSS NO. 6. STRESSES BY FORMULA IN *ENGINEERING NEWS*, OCTOBER 24, 1895, COMPARED WITH CORRECT STRESSES.

	Maximum Stress by Eng. News Formula.	Correct Stress.	Error %	Minimum Stress by Eng. News Formula.	Correct Stress.	Error %
BD	+118,050	+115,070	+ 2.59	− 64,100	− 65,260	− 1.77
DE	+ 97,950	+ 89,710	+ 9.19	−112,940	−114,570	− 1.43
EF				−228,370	−233,490	− 2.19
FF_1				−209,500	−214,150	− 2.17
ac	+ 25,630	+ 26,240	− 2.32	− 91,720	− 89,300	+ 2.71
cd	+112,640	+115,490	− 2.47	− 98,630	− 91,310	+ 8.02
df	+170,050	+172,110	− 1.20	− 34,380	− 26,470	+29.90
aB	+135,460	+131,920	+ 2.69	− 37,840	− 38,750	+ 2.36
Bc	+ 69,270	+ 74,030	− 6.43	− 58,930	− 56,080	+ 5.07
cD	+ 7,460	+ 4,950	+50.74	−113,090	−121,100	− 6.61
Dd	+ 82,630	+ 88,460	− 6.59	− 5,490	− 3,640	+51.00
dE				−159,070	−173,220	− 8.17
Ef	+140,230	+142,000	− 1.25			
fF	+ 91,080	+ 93,790	− 2.94			
ff_1	+209,500	+214,150	− 2.17			

TRUSS NO. 7. STRESSES BY THEOREM OF THREE MOMENTS COMPARED WITH CORRECT STRESSES.

	Maximum Stresses by Theorem of Three Moments.	Correct Stresses.	Error %	Minimum Stresses by Theorem of Three Moments.	Correct Stresses.	Error %
aB	+335,680	+274,610	+22.23	−107,650	−139,050	−22.58
BD	+227,530	+168,150	+35.31	−140,470	−171,870	−18.27
DE	+122,570	+ 64,060	+91.34	−173,270	−204,670	−15.34
EF	+ 22,730			−206,090	−247,690	−16.8
ac	+102,530	+132,430	−22.57	−320,640	−261,530	+22.6
cd	+165,030	+194,930	−15.34	−116,750	− 61,000	+91.39
de	+196,290	+243,100	−19.26	− 21,670		
ef	+260,070	+318,750	−18.41			
Bc	+110,770	+110,770	.0			
cD				−138,490	−138,490	.0
Dd	+ 64,170	+ 64,170	.0			
dE				−162,280	−162,280	.0
Ee	+ 96,250	+ 96,250	.0			
eF				−187,070	−187,070	.0
Ff	+313,880	+313,880	.0			

For trusses Nos. 1, 2, 3, 4, as will be seen, the error in R_1 does not exceed $1\frac{1}{2}$ per cent. in any case, while the error in R_3, though somewhat larger, is hardly worth noting. The stresses in truss No. 1 have been worked out for the correct reactions as shown. The error exceeds 2.3 per cent. in only two cases, and it will be observed that these are small stresses and would not affect the sections of the numbers.

The reactions in truss No. 5 are somewhat more in error, but the sections of the members would not be materially altered.

We may therefore say that nothing practical will be gained by applying the principal of virtual velocities to trusses in which the chords are nearly parallel. In trusses Nos. 7, 8, however, the case is quite different, and in designing trusses of those or similar forms, it would be well to change the theoretical reactions to conform to those here obtained or make a special investigation in each case.

Truss No. 6 appeared to merit a special investigation, because the conditions are materially different from those that

obtain in the other trusses. As this type of truss is very common, if the usual method of calculating the stresses is sufficiently accurate, it is worth while to know it; if not, it is worth while to know that and to make proper allowance for the errors. As the sections of the web members in the center panel are largely matters of judgment, they were first made about the same as is usually done in practice in similar cases, then these sections were doubled, and again these members were omitted altogether and the reactions calculated in each case. The reactions were also calculated according to the formula in *Engineering News* of October 24, 1895. The center panel was omitted and the truss made that much shorter and center-bearing. When the center panel is omitted and the truss shortened, the reactions agree very well with those obtained by the theorem of three moments. When only the web members are omitted in the center panel, the reactions agree fairly well with those obtained by the *Engineering News* formula. In the truss as first designed the reactions are generally between those obtained by the *Engineering News* formula and those obtained by the theorem of three moments, but rather nearer the latter; but they are still nearer the latter when the web members in the center panel are doubled.

The stresses throughout the truss were calculated by the theorem of three moments, ignoring the center panel, by the *Engineering News* formula and by the principle of virtual velocities as first designed. The results are shown. As will be seen, the results by the theorem of three moments are correct within 4 per cent. in all except eight cases, and in all but one of those the lesser stress is in error and would not therefore affect the sections of the members; besides, the errors are nearly all on the safe side.

If the stresses are calculated by the *Engineering News* formula, it will be seen that the maximum stresses in the chords and center posts are considerably more nearly correct than in the last case, while the errors in the web members are somewhat greater. This observation, of course, may not hold in all cases.

In the case of truss No. 7, the errors in the chord stresses are so great as to be scarcely admissible.

MR. JOHNSON—Gentlemen, we have listened to a very carefully prepared paper, and we can appreciate the great amount of work Mr. Whited has put on it, to arrive at these results.

It was voted that the thanks of the Society be tendered Mr. Whited for the excellent paper he had prepared.

MR. KAUFMAN—I would like to say that a few weeks ago there were given in the *Engineering News*, the results of some experiments made by Prof. Howe on a model of a bridge, and he corroborates everything that Mr. Whited has proved tonight. I could appreciate the vast amount of work Mr. Whited has placed upon this paper.

A MEMBER—I don't know very much about trusses, but I heard a story, about where some railroad officials and engineers went out to inspect the road. The superintendent was along, and they had champagne, etc. They came to an old wooden bridge which was nearly rotten. The superintendent took his cane and punched at the timbers for a while, and then asked, "What holds this bridge up? Why doesn't it fall down?" The engineer replied that it was the principle of stress that held it up.

MR. JOHNSON—On the lines I am connected with, out of something like twenty-three miles of bridges, we are fortunate enough to have only three draw bridges. One of them is a two-track strip with three trusses. Three or four years ago a train became derailed just as it was approaching the bridge, and knocked out the panels, but it didn't fall down. Whether it was the principle of stress that held it up, I don't know, but we didn't have any disaster.

On motion the society adjourned at 10:10 P. M.

REGINALD A. FESSENDEN,
Secretary.

MEETING OF THE CHEMICAL SECTION.

PITTSBURG, PA., February 22, 1900.

The regular monthly meeting of the Chemical Section was held February 22, 1900, at 8 : 15 P. M., in the rooms of the Society. The meeting was called to order by James O. Handy, chairman.

Present: Messrs. Camp, Mohr, Stahl, Loeffler, Handy, Arnold, McKenna and three visitors.

The minutes of the last meeting were read and approved.

Mr. J. M. Camp then read a paper entitled Laboratory Notes.

LABORATORY NOTES.

BY J. M. CAMP.

If apologies are required for the following notes, mine lie in the fact that they are detailed descriptions of some methods of analysis, partly new, that have stood the test of time and practical operations. They include a method for determining phosphorus in coke and coal, the determination of phosphorus in ores, pig iron and steel containing arsenic, and the determination of alumina as phosphate in ores and blast furnace cinder.

PHOSPHORUS IN COKE AND COAL.

One of the requirements at the laboratory of which the writer has charge, is the determination of the ash, sulphur and phosphorus, each day in an average sample of coke from all furnaces, of the previous day's consumption. The fusion of the ash, consisting as it does, of about 50 per cent. silica, 30 per cent. alumina and 10 per cent. sesquioxide of iron, with other bases, and its final evaporation to dryness to separate silica is at best a tedious process which can not be safely hastened. The result is that the time of analysis is unduly prolonged, consequently the following scheme was evolved, yielding excellent results in the minimum of time.

The sample of coke partly dried, and ground to pass through a forty mesh sieve, is delivered to the laboratory by the sampler on the afternoon of the day on which it is taken. This is dried at 100° C. for one hour, and when cool five grams are weighed off into a $1\frac{3}{4}$ inch porcelain crucible. This is left in the muffle furnace over night, and in the morning the lump of ash and any particles adhering to the crucible are transferred to a 30 c.c. platinum crucible, mounted on a platinum tripod. About 5 c.c. of dilute hydrochloric acid are now added, one acid to two of water, and about 10 c.c. of hydrofluoric acid, and the crucible and tripod are placed directly on the top of the chimney of an Argand burner and the flame so regulated that the solution will not boil. In from twenty to thirty minutes the solution is to dryness and dried to drive off the last traces of hydrofluoric acid, but not baked, as this will render some of the bases insoluble in the dilute acid to be subsequently used. When cool, about 15 c.c. of the same dilute hydrochloric acid are added and the crucible warmed until all is in solution. The contents of the crucible are now transferred to a 12 cm. evaporating dish and 5 c.c. of strong nitric acid added. The bulk of the solution now aggregates about 75 c.c., and the solution is boiled for one or two minutes and then filtered, to remove any possible traces of silica or unconsumed carbon, into a sixteen ounce flask.

The treatment now is the same as that previously described before this Society,[1] to wit, the addition of 25 c.c. of strong ammonia, and then strong nitric acid until the precipitated iron and alumina are just dissolved, and then 5 c.c. in excess, making a total of about 25 c.c. strong nitric acid.

The solution is brought to 85° C. and 75 c.c. of molybdate solution blown in by aid of a pipette, after which the solution is kept agitated for about five minutes, and is then filtered through a weighed filter paper that has been dried at 115° to 130° C. and weighed between watch-glasses. The

1. Proc. E. S. W. Pa. Vol. xi, p. 251.

precipitate is washed with a two per cent. solution of strong nitric acid, dried one hour at the above temperature and weighed between watch-glasses. 1.63 per cent. of its weight is taken for phosphorus.

In the case of coals the treatment is exactly similar, except that the coal is usually coked in a large platinum crucible and then, to save the platinum crucible from the protracted heating, the coke is transferred to a porcelain crucible for complete combustion in the muffle preferably over night.

THE DETERMINATION OF PHOSPHORUS IN ORES, PIG IRON AND STEEL CONTAINING ARSENIC.

For the exact determinatien of phosphorus in ores, particularly manganese ores, coming as they do from all quarters of the globe, and in pig iron or steel containing arsenic, although this impurity is not an every day occurrence, a method is very desirable wherein at some stage of the analysis the arsenic can be eliminated without a marked change in the essential details of the regular phosphorus determination and without prolonging the time of the analysis beyond that of the regular routine work. Numerous experiments have been made by the writer along these lines, mainly in the attempt to reduce the concentrated ferric chloride solution to the ferrous state, and then vo latlilizing the resulting arsenious chloride but without marked success, until, acting on the suggestion contained in a paper by Mr. E. D. Campbell,[2] describing briefly some experiments made by his students who used oxalic acid as the reducing agent, the following scheme was worked out. Excellent results were obtained up to one per cent. arsenic. The method for ores only will be given; its application to pig iron or steel will be readily seen.

Five grams of the ground and dried sample are weighed off into a 12 cm. porcelain dish with watch-glass cover and 50 c.c. of strong hydrochloric acid added and the solution boiled

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gently for about thirty minutes. It is now diluted with sufficient cold water to prevent cutting the filter paper and filtered into another dish of the same size.

This solution will contain all the unvolatilized arsenic in the ore, and it is placed on the steam bath to go to dryness over night. The residue is burned and fused with the mixed carbonates and the fusion allowed to harden around a platinum rod. The crucible is now warmed, and the greater bulk of the fusion removed on the platinum rod. This, while still hot, is placed in the dish with cover, in which the ore was originally dissolved and containing ten or fifteen c.c. of water. Dilute hydrochloric acid is added to the crucible and warmed, and this process is repeated until all of its contents are removed and added to the dish containing the fusion. An excess of strong hydrochloric acid is now added to dissolve any of the remaining fusion, and this dish is placed with the other on the sand bath. In the morning, to the dish containing the dried mass from the original filtrate, two grams of pure oxalic acid are added and 50 c.c. of strong hydrochloric acid, and the solution, with watch-glass cover, evaporated to dryness by hard boiling, but not baked. When cool add 30 c.c. strong hydrochloric acid and evaporate to first appearance of insoluble ferric chloride, remove from the light and add 10 c.c. strong nitric acid when the violent action has ceased, warm until all is in solution, dilute with cold water and filter into a sixteen ounce flask, using two per cent. nitric acid for washing. In the meantime, to the dish containing the fusion, dilute hydrochloric acid is added just sufficient to moisten and enough hot water to dissolve the chlorides. This is warmed until all is in solution but the separated silica and filtered into the same flask with the original filtrate. The phosphorus is now precipitated as above described for phosphorus in coke.

THE DETERMINATION OF ALUMINA AS PHOSPHATE IN ORE AND BLAST FURNACE CINDER.

The greatest advantages which precipitating and weighing alumina as phosphate has over the hydrate precipitation is in ore analysis, where with the latter method, the iron and alumina are weighed together, the iron being finally determined by solution of the precipitate and titration, or preferably titration in another portion of the same sample. All the errors of the entire manipulation are thus thrown on the alumina, the lesser dog. In the phosphate precipitation, however, the alumina is determined in a separate portion, and is responsible only for its own manipulative errors. In blast furnace cinders, to determine the alumina, which is the laboratories' daily task, the determination of iron is entirely obviated. Most furnace managers are content to receive the silica and alumina in each day's cinders, counting the balance as bases, with a full analysis at regular stated intervals. The iron not being an essential component of the cinder its determination in a cinder of a normal working furnace where it is little more than a trace, is useless, while, with an abnormal working furnace, where it may be high, the manager has something else on hand to worry him of much more importance.

The filtration and washing of the phosphate precipitate are also much faster than the same operation with the hydrate precipitate; this statement applies particularly to cinders, where the large amount of alumina apparently coagulates the separated sulphur and precipitate settles rapidly leaving the supernatant liquid practically clear and readily decanted. In ores where there is much less alumina, more free sulphur is in suspension and a partial but not aggravating clogging of the filter occurs.

One disadvantage of the phosphate method is that there is no end point to the washing of the precipitate, it being slightly soluble in the wash water, and after the tenth washing showing with molybdate solution a fairly uniform volume of phospho-

molybdate precipitate in equal volumes of the successive filtrates up to the twentieth washing. The addition of acetic acid and ammonium acetate to the wash water gave a slightly greater weight of aluminum phosphate from a slag of known composition, but still showed the phosphate in the filtrates up to the twentieth washing. It is important that the precipitate be washed thoroughly ; otherwise the platinum ware, if used, will suffer.

The method as used on ore and cinders is as follows :

To the cold hydrochloric acid filtrate from the silica of one gram of ore or cinder diluted to about 400 c.c. in a number five breaker, add 30 c.c. of a 10 per cent. solution of ammonium phosphate and then ammonia until a faint permanent precipitate is formed. 1.5 c.c. of strong hydrochloric acid is now added, and for ores, on account of the greater bulk of iron present, 50 c.c.; and for cinders, 30 c.c. of a 20 per cent. solution of sodium hyposulphite. The beaker is now placed over the light and heated just to boiling. Now in the same graduate measure off 8 c.c. of strong acetic acid and 15 c.c. of a 20 per cent. solution of ammonium acetate and add to the boiling solution and boil ten minutes. If the latter is added before the solution is boiling or near the boiling point the precipitate will be flocculent and difficult to filter. Remove beaker from the light and allow precipitate to subside, decant clear solution and wash precipitate on to the filter and then wash ten times with hot water. Transfer precipitate to platinum crucible without lid and place in front part of the muffle; when paper is charred transfer crucible to hottest part of muffle till burned. Cool and weigh; 41.85 per cent. of the weight is alumina.

G. O. Loeffler,

Secretary C. S.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and third regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture Room of the Society's House, 410 Penn Ave., Pittsburg, Pa., Tuesday evening, March 20, 1900, forty-nine members and visitors being present. The meeting was called to order at 9:30 by Mr. Chas. S. Scott.

The minutes of the previous meeting were read and approved.

For the board of Directors, the following applicants were reported as passed and to be voted for at the next regular meeting:

WM. HENRY BAILEY, - -	Mechanical Draughtsman, With Thos. Carlin's Sons Co., Allegheny, Pa.
ALEX. W. PATTON, - -	Engineering Department, Pittsburgh Coal Co., Pittsburg, Pa.
WM. H. LEDGER, - -	Engineer, Keystone Bridge Works, Pittsburg, Pa.
WILFRED DUDLEY CHESTER,	Salesman, Babcock and Wilcox Co.,235 McKee Place, Pittsburg, Pa.
ARTHUR BYRON CAPEN, -	Pittsburg Agent Babcock and Wilcox Co., Hotel Schenley, Pittsburg, Pa.
GEORGE J. BRYEN, . -	Master Mechanic, Duquesne Blast Furnace and Steel Works, Duquesne, Pa.

The following gentlemen were balloted for and duly elected to membership:

LEWIS W. FOGG, - -	Mining Engineer, For American Coke Co., Latrobe, Pa.
E. M. HERR, - - -	Asst. General Manager, Westinghouse Air Brake Co., Wilmerding, Pa.
FRANK S. JACKMAN, - -	Engineer and Superintendent, Pittsburg Manufacturing Co., 28th and Railroad Streets, Pittsburg, Pa.
RICHARD L. SMITH, -	Civil Engineer, 1011 Park Building, Pittsburg, Pa., Castle Shannon, Pa.
JAMES D. WHITE, - -	Civil Engineer, 730 Park Building, Pittsburg, Pa.

The Library Committee reported progress.

The House Committee reported that some repairs were needed and that they were looking up the matter.

For Finance Committee Mr. Davidson made the following report:

PITTSBURG, PA., March, 20th, 1900.

Report of Special Committee appointed to consider the question of the Society purchasing property for a Society House.

Your committee has taken up the subject of the Society owning its own property, and would respectfully report:

FIRST. That we think it advisable that this Society does not at this time, exercise its option on the property now occupied by it.

SECOND. That, in our opinion, the present is a most favorable time for the Society to take steps toward establishing a special fund, the purpose of which fund would be to purchase at some future time, a suitable property as a site for a permanent home for the Society.

The ways and means for this special object have been considered, and a number of financial plans have presented themselves. It is not necessary that the full value in cash of a

proposed home should be raised, as a mortgage could be carried upon it, but the amount to be borrowed should be kept within such a limit that the interest on same, with the taxes on the property added, less rentals, should not exceed what would be equal to a rental compatible with our income. Just what this sum should be is a question that can be determined only in connection with the value of properties that may be acceptable to the Society, but it would seem to us that the sum of at least $15,000 should be raised by subscription among the members of the Society and its friends. We believe that this sum can be raised if the proper plan of doing so is pursued. We further believe that the first step in any plan is that each member of the Society should contribute at once the sum of ten dollars to the proposed fund. This is a sum of money within the means of each and every member, and the payment of which by all the members would not only yield a handsome sum, but each member so paying would have an equal interest with all other members. The amount so paid can be put out on interest at once, and thus the principal may be increasing. If the Society will do this much, we will promise to work hard to the end that substantial additions to the fund may be made promptly. With a fund thus created, the Society will be prepared to provide the balance needed when it is found necessary and expedient.

The experience of the Society has been that when it occupied good and convenient quarters, it prospered. In the past four years it has been fortunate in being able to rent just what was needed, and at a very modest rental. These conditions will not always maintain. The Society requires a large floor space, say not less than 1,500 square feet. Its rooms must be in the business part of the city and easily accessible to the street. The building in which it should be located, should be as nearly fire-proof as possible, to carry the risk on its library at a low rate. This will mean, at no very distant day, a much larger rental than we have been accustomed to pay. Our

present income should not be drawn upon for this purpose. A special fund such as we recommend, even if it be not applied to purchasing our own property, can, through its interest returns, aid in paying the rent of suitable quarters.

If our ideas thus crudely expressed meet the views of the members present at this meeting, it is hoped that you will take such action tonight as is necessary to establish and set aside a special fund to be known as "The Property Fund," into which shall be paid all sums intended for this special purpose, and no part of which shall be used for any other purpose than the purchase or maintenance of suitable quarters for the Society.

All of which is respectfully submitted:

GEO. S. DAVISON,
EMIL SWENSSON,
WM. METCALF,
THOS. H. JOHNSON,
JNO. A. BRASHEAR,
Committe.

Moved that report be accepted and the recommendations made by the Committee be accepted.

Motion amended by Mr. Wilkins to the effect that present Committee be continued and authorized to proceed with the collection of funds.

Moved by Mr. Camp that report be amended by striking out the word "maintenance" from report. Motion lost.

Amendment of Mr. Wilkins and original motion put and carried.

The paper of the evening, entitled "Astronomical and Mechanical Equipment of the new Allegheny Observatory," was then read by the author, Prof. F. L. O. Wadsworth.

A vote of thanks was tendered the author by the Society, and upon motion the Society adjourned 10:45 P. M.

REGINALD A. FESSENDEN,
Secretary.

MEETING OF THE CHEMICAL SECTION.

PITTSBURG, PA., March 22d, 1900.

Meeting called to order by the Chairman, J. O. Handy. Seven members present.

The minutes of the previous meeting were read and approved.

The Chairman appointed Prof. F. C. Phillips and A. G. McKenna on the Committee of Chemical Literature.

Prof. Phillips read an interesting account of recent chemical literature.

The properties of the new element, radium, were described. Hempil's new edition of his book on Gas Analysis was criticised. Many other matters were discussed.

Adjourned at 10 :10 P. M.

G. O. LOEFFLER,
Secretary.

SYNTHETIC INDIGO.

BY EDWARD S. JOHNSON.

It is a matter of very general observation that in this center of occidental civilization, the United States, the reception accorded scientific discovery by the mass of intelligent men is notably apathetic unless prospect for immediate utilization is evident. This fact is pointed to as a marked characteristic of the American by the enlightened nations of the Old World where, preeminently in Germany, the greatest importance is attached to scientific research and discovery whatever the momentary outcome.

The causes of these divergent social conditions cannot consistently be made here a subject of minute discussion. It suffices to refer to the influence of environment and other factors of natural selection in their bearing upon the older civilized nations treated purely as modified varieties or races of the *genus homo*, and the intensity, not to say fierceness, of the struggle for existence occasioned by the narrow limits naturally prescribed for a multitude of combatants. Such conditions have resulted in resort to all the refinements of human intelligence to maintain a successful struggle; in all branches of industrial affairs, aid has been drawn from institutions of learning with such apparent advantageous effect as to establish in those countries where scientific light is brightest an intimate connection with, and supreme respect for, science in its purity and the increasing host of its devotees.

Cultured young America has not been altogether backward in an appreciation of such matters in what has been his absorbing occupation, the amassing of wealth. The untold natural resources of a new land he has in part brought to light,

utilized to his own comfort, and set his sons of the last decades of the century upon a career of development unparalled in rapidity and immensity to a degree which makes America an object of utter amazement to the more cultured of older civilizations. With this growth has come a severity of competition in all those forms of great organized effort of civilized man, known in part in social economics as industry and commerce. Natural science is exerting in all departments of industry an elevating influence. The united efforts of botanist, zoologist and chemist are fast placing agriculture upon a rational footing, and those manufacturing industries producing the great staples which serve as raw materials for the almost innumerable objects of cultured necessity and comfort are directed each year more fully than ever by the deductions of physical and chemical science.

Many stages of progress must, however, still be attained and passed before American industry may generally be regarded as upon the level of that of the leading nations of continental Europe in respect to an appreciation and application of scientific methods and observations. That period of development has hardly passed in which a proffered advantage is eagerly accepted, fairly grasped by the beneficiary, while the benefactor is relegated to forgetfulness or, if remembered, referred to with a kindly commiserative, amused smile when engaged upon problems of science not promising an instant contribution to material wealth. Leaving the figure of the youth in the first years of robust manhood, with fine muscular development and general functions, but with an indefinite sense of the source of his well-being, American industrial conditions may be again likened, in a measure at least, to those of the newly discovered gold field. Methods of operating are adapted to a dazzling natural wealth of raw material to be converted into finished product by a mere turn of the hand, for the very picking up, or, at most, the crudest forms of placer mining. The mass of fabulous treasure contained beneath the surface in great alluvial

deposits and beds of quartz rock is neglected for the time, and left for the systematic and refined operations of the metallurgist who in after years applies the knowledge of his science with the utmost economy in the transformation of his raw materials. This latter period of the gold field's history illustrates in main features European industrial conditions.

Nothing offers a more forceful illustration of the important part which the cultivation of science, for its own sake, has played in their development to the present exalted level than the following, at first glance apparently insignificant incident from the history of synthetic indigo.

In pursuance of confirmation of his theory of the relationship of indol to the compounds of the indigo-group, Baeyer[1] sought evidence in the reduction of isatine to dioxindol, oxindol and finally indol. Success was ultimately achieved but not without the expenditure of, seemingly, a wasteful amount of time and energy to discover the right reducing agent. This was found in the now classic, although common, zinc-dust of the laboratories, which has been, and is, of greatest service to the practice of chemical research, and literally has led to the establishment of a gigantic chemical industry. It was by the application of the new reducing agent that Graebe and Liebermann, respectively assistant and pupil in Baeyer's laboratory, in 1868, discovered the constitutional relation of alizarine to anthraquinone and anthracene, and soon were led to invent means for a synthesis of the celebrated coloring matter which, authentic accounts relate, produced the flaming reds of the Far East centuries and centuries ago.

The cultivation of the madder plant, the source of this ancient dye-stuff, gradually crept westward, and it is related[2] that, as early as the seventh century, the plant was grown on a small scale in France which became, however, several centuries later, with favorable climatic conditions, the most ex-

1. Ber. d. deutsch. chem. Ges. *13,* 2254; *Ueber. d. Beziehungen d. Zimmtsaeure zu d. Indigogruppe.*

2. Schultz: *Chem. d. Steinkohlentheers,* II, 584.

tensive European producer of madder, the ground root of the color-bearing plant. Besides France, Holland engaged notably in the cultivation. In the season of 1862-3, the production[1] of madder in France had attained the seemly proportions of 26,-850 tons; ten years later, 1871-2, and two years after the introduction of artificial alizarine, 25,000 tons were still harvested; in 1878-9 this sum had decreased, gradually at first, and then by leaps and bounds, to 500 tons. A similar, but less rapid, fate overtook the production in other madder-growing lands, dwindling the estimated total output of the root, 70, 000 tons, for the years about 1868 to a mere trifle. The rapid decline in the cultivation was accompanied, which was still more disastrous to the madder-grower, by a fall of seventy-five per cent. in price. This is concretely exhibited by the fact that in 1860 the value of madder and garancine exported by France was nearly $6,250,000, an amount which had decreased, for the same items in 1876, to somewhat more than $900,000.

By these industrial changes, no mean crisis had presented itself. Vast tracts of valuable agricultural land must be turned to lucrative account, and extensive commercial organizations must be dissolved or seek excuse for existence in other fields. While a temporary disturbance was occasioned, the general effect can only be regarded as beneficent; the development of the great staples of agriculture was elevated where such was urgently needed by the return of former madder-fields to their cultivation. It is most interesting to note the influence of the innovation upon chemical industry, the facts of which relate a familiar story, but one of such cardinal character as to bear frequent recounting, marking, as it does, an epoch in the history of applied chemistry. By the announcing of a practicable manufacture of alizarine from anthracene, the preparation of the latter became one of the most important and lucrative operations of the coal-tar distilleries. For the conversion of anthracene into anthraquinone, a heavy demand was made upon

1. Schultz: *Chem. d. Steinkohlentheers*, II, 597.

the producers of the alkali chromates. In succeeding transformations, the sulphonation and oxidizing fusion, fuming sulphuric acid, caustic alkali, and potassium chlorate are required. Their supply by the acid, alkali and chlorate industries gave each a strong forward impulse, adding heavily to the production.

This splendid industrial expansion, which the enthusiastic chemist cannot regard but with keen pleasure and pride, may be directly referred for its origin to the simple observation of the value of zinc-dust in the study of a group of substances belonging in a totally different field of scientific research from that which by its means was later illumined and cultivated with marvelous results. The influence of this re-agent as an industrial factor did not cease with the founding of the alizarine manufacture. Its part in revealing, in the hands of Baeyer, the relationships of indigo, and leading thus finally, in the course of years and a series of researches of unequalled brilliancy to practicable methods for its synthesis, marks the distant beginning of another economic change now steadily progressing toward certain, successful culmination.

I. The Synthesis of Indigo.

The wonderful investigations of Baeyer and his pupils, which almost exclusively underlie this development are so remarkable as examples of consistently prosecuted, perspicuous, resourceful and prolific research, and withal so absolutely essential to a discussion of synthetic indigo, that they will throughout be reviewed somewhat in detail. To this will be added a brief consideration of the chief of more recent, technically important syntheses.

1. BAEYER'S SYNTHESES.

The first of these most interesting formative processes is based upon *o-amidophenylacetic acid.*[1]

1. Baeyer: *Synthese d. Isatins u. d. Indigblaus*, Ber. d. deutsch. chem. Ges., *11*, 1228.

$$C_6H_4<\begin{matrix}\overset{1}{C}H_2COOH\\ \overset{2}{N}H_2\end{matrix}$$

The anhydride of the acid was shown by Baeyer[1] to be identical with oxindol, one of the compounds of the indigo-group then already known and in the investigation referred to shown to be

$$C_6H_4<\begin{matrix}CH_2\\NH\end{matrix}>CO$$

the anhydride of *o*-amidophenylacetic acid. The preparation of isatine,

$$C_6H_4\begin{matrix}CO\\ \quad\\ N\end{matrix}C.OH$$

had already been long before realized by the work of Baeyer and Emmerling[2] by the action of phosphorus, phosphorus dichloride, and acetyl chloride upon that substance. The problem therefore consisted in substituting H_2 in the methylene-group, CH_2, of oxindol by oxygen. Great difficulty was experienced in effecting the change, being found impossible by direct oxidation. With the idea of facilitating the desired reaction, chlorine, bromine, etc., were substituted in the methylene-group, but all unsuccessfully; by means of nitrous acid and thus the introduction of the isonitro-group, NOH, and reduction, the oxidation was readily and perfectly accomplished:

$$\underset{\text{Isonitrosooxindol.}}{C_6H_4<\begin{matrix}C:NOH\\NH\end{matrix}>CO} \qquad \underset{\text{Amidooxindol.}}{C_6H_4<\begin{matrix}CH.NH_2\\NH\end{matrix}>CO} \qquad \underset{\text{Isatine.}}{C_6H_4\begin{matrix}CO\\ \quad\\ N\end{matrix}C.OH}$$

The slight yield by the old process for bringing about the last stage of the operation was later[3] improved and the nature of the reaction more fully explained by the use of phosphorus pentachloride. Hereby isatine chloride,

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1. Ibid: *Synthese d. Oxindols*, Ber. d. deutsch. chem. Ges., *11*, 584.
2. Ber. d. deutsch. chem. Ges. *3*, 514.
3. *Ber. d deutsch. chem. Ges.* 11. 1296; and 12. 456.

$$C_6H_4<\begin{matrix}CO\\ N\end{matrix}>C.Cl$$

is formed and by reduction (P, Zn+HCl, etc.) transformed into indigo.

$$C_6H_4<\begin{matrix}CO\\ NH\end{matrix}>C=C<\begin{matrix}CO\\ NH\end{matrix}>C_6H_4$$

"Thereby for the first time a synthesis of indigo from coal-tar has been effected."[1] It dates from the year 1878.

Following shortly, in 1880, upon the *o*-amidophenylacetic acid synthesis, came the famous investigations starting with *o-nitrocinnamic* acid. They brought to light a series of most peculiar and astonishing substances, the study of which in the main definitely made plain the constitution of indigo.

o-Nitrocinnamic acid,

$$C_6H_4<\begin{matrix}CH{:}CH.CO_2H\\ NO_2,\end{matrix}$$

by addition of bromine is converted into *o*-nitrodibromcinnamic acid,

$$C_6H_4\begin{matrix}/\overset{1}{C}HBr.CHBr.CO_2H\\ \backslash\overset{2}{N}O_2\end{matrix}$$

By alkali in the cold, the bromine may be removed in the form of alkali bromide leaving,

$$C_6H_4<\begin{matrix}\overset{1}{C}\equiv C.COOH\\ \overset{2}{N}O_2\end{matrix}$$

o-nitrophenylpropiolic acid. This with dilute alkali and mild reducing agents, such as milk-sugar, grape-sugar and xanthates, produces indigo.

With hypochlorites in alkaline solution, *o*-nitrocinnamic acid further yields *o*-nitrophenylchlorlactic acid,

1. Ber. d. deutsch. chem. Ges., *11*, 1228.

$$C_6H_4<\begin{matrix}\overset{1}{C}H.OH.CH.Cl.CO_2H\\ \overset{2}{N}O_2\end{matrix}$$

Alcoholic solution of alkali extracts one molecule of hydrochloric acid and *o*-nitrophenyloxacrylic acid,

$$C_6H_4<\begin{matrix}\overset{1}{C}.OH:CH.CO_2H\\ \overset{2}{N}O_2\end{matrix}$$

results. Heating at 100° in the presence of a solvent, such as acetic acid or phenol, completes the conversion into indigo. The yield of the latter form of the *o*-nitrocinnamic acid process is slight, while the first mentioned amounts to 70 per cent. of the theoretical.[1]

Baeyer and Drewsen in 1882 published the discovery by them of the formation of indigo from *o-nitrobenzaldehyde* and acetone. This at that time unaccountable process was fully investigated by its discoverers. By it indigo is formed when a mixture of the aldehyde and acetone, acetaldehyde, or phenylglyoxylic acid is warmed in the presence of alkali.

The technical starting-point for the preparation of indigo by this method is toluene; this hydrocarbon is nitrated, producing as a main product the *o*-nitroderivative. This is chlorinated in the methyl-group, a reaction which is only possible to the extent of about 50 per cent. without introducing chlorine into the benzene-ring also. The separating of the *o*-nitrobenzylchloride formed, from unaffected nitrotoluene, is accomplished by the action of aniline upon the mixture, producing *o*-nitrobenzylaniline,

$$C_6H_4<\begin{matrix}\overset{1}{C}H_2.HN.C_6H_5\\ \overset{2}{N}O_2\end{matrix}$$

By oxidation *o*-nitrobenzylideneaniline is formed,

$$C_6H_4\begin{matrix}/\overset{1}{C}H:N.C_6H_5\\ \backslash\overset{2}{N}O_2\end{matrix}$$

1. Reissert: *Indigosynthesen*, 7.

Boiling with hydrochloric acid converts the substance into the aldehyde sought and aniline hydrochloride.

The transformations involved in the conversion of *o*-nitrophenylpropiolic acid into indigo are of somewhat complicated nature. Their explanation is based upon certain experimentally derived facts, and assumptions from analogy. Baeyer[1] observed that phenylpropiolic ethylester by the action of slightly diluted sulphuric acid is converted into benzoylacetic ester:

$$\underset{\text{Phenylpropiolic ethylester.}}{C_6H_5.C{\equiv}C.CO_2.C_2H_5} + H_2O(H_2SO_4) =$$

$$\underset{\text{Benzoylacetic ethylester.}}{C_6H_5.CO.CH_2.CO_2.C_2H_5}$$

It is also a general observation that nitro-groups united to the benzene-ring are deprived partially or even wholly, without the use of reducing agents, of oxygen by mobile (easily oxidizable) hydrogen atoms held by carbon attached to the benzene-ring in *o*-position to the nitro-group. Moreover it is known that carbonyl-groups (=CO) of aldehyde or ketone nature react with phenylhydroxylamine, cause water to separate, and form compounds which contain the combination of atoms,

$$C_6H_5{-}\underset{\diagdown\ O\ \diagup}{N{-}C}<$$

With these facts in mind, analogous transformations may may be readily recognized as possible in the case of o-*nitrophenylpropiolic ethylester*:

$$C_6H_4<\begin{matrix}\overset{1}{C}{\equiv}C.CO_2.C_2H_5\\ \overset{2}{N}O_2\end{matrix} + H_2O(H_2SO_4) =$$

$$C_6H_4<\begin{matrix}\overset{1}{C}O.CH_2.CO_2.C_2H_5\\ \overset{2}{N}O_2\end{matrix}$$

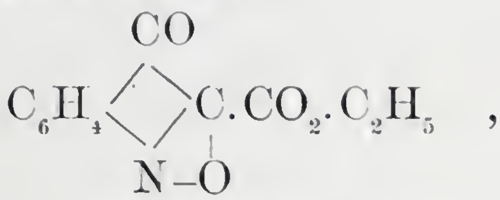
In the *o*-nitrobenzoylacetic ethylester thus formed, intramo-

1. Ber. d. deutsch. chem. Ges., *15*, 2705; further in same connection compare Reissert: *Indigosynthesen*, 19—23, and the literature there referred to.

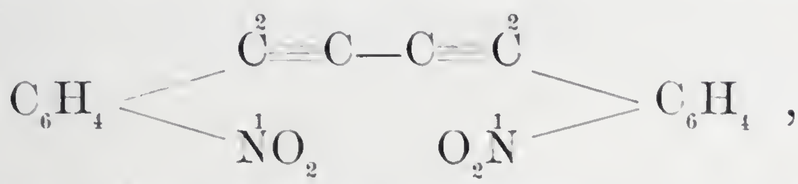
lecular reduction produces *o*-hydroxylaminobenzoyloxalic ethylester,

$$C_6H_4<\begin{matrix}\overset{1}{C}O.\ CO.\ CO_2.\ C_2H_5 \\ \overset{2}{N}HOH\end{matrix}\quad ,$$

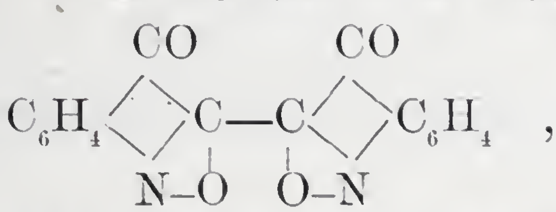
which becomes by anhydrization,



isatogenic ethylester. As to dinitrodiphenyldiacetylene,



which contains the characteristic group of *o*-nitrophenylpropiolic acid twice, it is at once seen how diisatogen,



may be derived. By comparison of its formula with that of indigo, it is apparent that the latter is produced by the removal from diisatogen of two atoms of oxygen and the addition of two atoms of hydrogen, in other words, by reduction. This relationship is in perfect accord with the actual observation.

In the case of the o-*nitrobenzaldehyde synthesis*,

$$C_6H_4<\begin{matrix}\overset{1}{C}HO \\ \overset{2}{N}O_2\end{matrix} + H.CH_2.CO.CH_3\quad ,$$

o-Nitrobenzaldehyde. Acetone.

o-nitropnenyllactic ketone,

$$C_6H_4<\begin{matrix}\overset{1}{C}HOH.CH_2CO.CH_3 \\ \overset{2}{N}O_2\end{matrix}\quad ,$$

is formed as a first phase of the reaction, and is transformed, by internal reduction of the nitro-group, to

$$C_6H_4 < \begin{array}{l} \overset{1}{C}HOH.CO.CO.CH_3 \\ \overset{2}{N}HOH \end{array}$$

The alkali added to the original mixture separates acetyl (—$CO.CH_3$) as acetate. This and anhydrization produce

$$C_6H_4 \begin{array}{c} CHOH \\ \diagup \quad \diagdown \\ \diagdown \quad \diagup \\ N - O \end{array} CH$$

which may be conceived as changing, by the migration of an hydrogen atom, to

$$C_6H_4 \begin{array}{c} CHOH \\ \diagup \quad \diagdown \\ \diagdown \quad \diagup \\ NH \end{array} CO$$

The splitting off of two molecules of water from two molecules of such a combination would result in the formation of indigo.

With the last named synthesis, the following shares the greatest technical importance;[1] it is the

2. *HEUMANN SYNTHESIS.*

In its most recent form, it consists in the preparation of of *indoxylic acid*,

$$C_6H_4 \begin{array}{c} COH \\ \lessgtr \\ NH \end{array} C.CO_2H,$$

which is readily converted into indigo, by alkaline fusion of phenylglycine-*o*-carboxylic acid:

$$C_6H_4 < \begin{array}{l} \overset{1}{C}O_2H \\ \overset{2}{N}H.CH_2CO_2H \end{array} = H_2O + C_6H_4 \begin{array}{c} COH \\ \lessgtr \\ NH \end{array} C.CO_2H.$$

1. Friedlaender: Fortschritte d. Theerfarbenfabrikation, IV, 1027.

The original raw material for the process is naphthalene from which, by the action of concentrated sulphuric acid at high temperatures, phthalic anhydride,

$$C_6H_4<{CO \atop CO}>O,$$

is obtained. From this, phthalimide,

$$C_6H_4<{CO \atop CO}>NH\,,$$

is prepared by means of ammonia gas. Phthalimide in alkaline solution is converted by sodium hypochlorite into anthranilic acid :

$$C_6H_4<{CO \atop CO}>NH+NaOCl+3\,Na\,O\,H =$$

$$NaCl+Na_2CO_3+H_2O+C_6H_4<{\overset{1}{C}O_2Na \atop \overset{2}{N}H_2}$$

Sodium anthranilate.

With monochloracetic acid, phenylglycine-*o*-carboxylic acid is formed :

$$C_6H_4<{\overset{1}{C}O_2H \atop \overset{2}{N}H_2}+Cl.\,CH_2.\,CO_2H=HCl+C_6H_4<{\overset{1}{C}O_2H \atop \overset{2}{N}H.CH_2.CO_2H}$$

II. The Constitution of Indigo.

The leading motive of the classic investigations of Baeyer in the indigo series was the desire to establish "the place of each atom in the indigo molecule experimentally"[1] and the relation of all bodies of the group to indol,

$$C_6H_4{\diagup CH \diagdown \atop \diagdown NH \diagup}CH\,,$$

as generatrix.[2]

1. Baeyer: *Ueber d. Verb. d. Indigoreihe*, Ber. d. deutsch. chem. Ges. *16*, 2188.
2. Ibid.: *15*, 775.

It was by no mere chance that the formation of indigo from *o*-nitrocinnamic acid was discovered, but by a deliberately formed conclusion drawn from the facts observed in studying the linking of the nitrogen atom of an amido-group of a benzene-ring, in ortho-position to a chain of two or more carbon atoms, thus:

$$C_6H_4 \begin{array}{l} \overset{2}{C}\text{—}C\text{—}C\text{—} \\ \overset{1}{N}H_2 \end{array}$$

It was thereby and in the synthesis of bodies of the indigo group[1] found that the nitrogen of the amido-group unites with the second or third carbon atom of the chain but not, it seems, with those more distant. The formation of such rings is not dependent upon the presence of the carboxyl-group. Thus a substance resembling quinoline,

$$\begin{array}{ccc} & CH & \\ & & \diagdown\!\!\diagdown\ CH \\ C_6H_4 & & \\ & \diagdown & /\!\!/\ CH \\ & N & \end{array} ,$$

is formed when the third carbon atom is present in ketone-form as in phenylethylmethyl ketone,

$$C_6H_5.\ CH_2.CH_2.\ CO.CH_3,$$

and it may be said in advance with great probability of correctness that whenever the second or third carbon atom is present as an alcohol, aldehyde or ketone-group, an inner anhydride will result, which belongs either to the indol or quinoline series. It was then further observed that the methylketone of *o*-amidophenylacetic acid,

$$C_6H_4 \begin{array}{l} / \overset{1}{C}H_2.CO.CH_3 \\ \ \ \overset{2}{N}H_2 \end{array} ,$$

1. Throughout, the original discussion of the subject, as found in the literature to which reference has been or will be made, is here or will be in other similar instances closely followed.

produces a substance,

$$C_6H_4 \left\langle \begin{array}{c} CH_2 \\ N \end{array} \right\rangle C.CH_3,$$

of the composition of a methylindol. If a ketone shows this reaction, it is to be expected that the corresponding aldehyde,

$$C_6H_4 \left\langle \begin{array}{l} \overset{1}{C}H_2.COH \\ \overset{2}{N}H_2 \end{array} \right.$$

would give a body,

$$C_6H_4 \left\langle \begin{array}{c} CH_2 \\ N \end{array} \right\rangle CH,$$

isomeric with indol,

$$C_6H_4 \left\langle \begin{array}{c} CH \\ NH \end{array} \right\rangle CH$$

For this purpose, exactly as in the unnitrated body, it would be necessary to prepare the aldehyde by means of *o*-nitrophenyloxacrylic acid,

$$C_6H_4 \left\langle \begin{array}{l} \overset{1}{C}(OH):CH.CO_2H \\ \overset{2}{N}O_2 \end{array} \right.$$

This led then to the conviction that in o-nitrocinnamic acid,

$$C_6H_4 \left\langle \begin{array}{l} \overset{1}{C}H:CH.CO_2H \\ \overset{2}{N}O_2 \end{array} \right.$$

a better starting-point for the preparation of indigo, isatine and indol would be found than in *o*-amidophenylacetic acid,

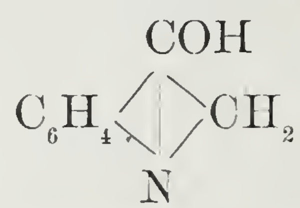
$$C_6H_4 \left\langle \begin{array}{l} \overset{1}{C}H_2CO_2H \\ \overset{2}{N}H_2 \end{array} \right.$$

despite the loss suffered by the splitting off of carbonic anhydride.[1]

1. Baeyer: *Ueber d. Bezieh. d. Zimmtsaeure zu d. Indigogruppe*, Ber. d. deutsch. chem. Ges. *13*, 2254.

A series of most remarkable substances was developed—o-nitrophenylpropiolic acid, isatogenic acid, indoxylic acid, indoxyl and derivatives, indoxanthinic acid, dinitrodiphenyldiacetylene, diïsatogen—and gave up under the persistent and skillful inquisition and acute perception of their discoverer the secret of the constitution of indigo.

The way through *o*-nitrophenylpropiolic, isatogenic, and indoxylic acids to indoxyl gave important insight into the question. Indoxyl warmed with *o*-nitrophenylpropiolic acid in alkaline solution yields indigo. Indoxyl, which is derived from *o*-nitrophenylpropiolic acid, appears therefore possibly in the part of an intermediate product in the formation of the coloring matter which it produces when oxidized. Indigo, however, it was argued,[1] is of much more complicated nature than indoxyl, giving, for instance, upon reduction substances of the character of complicated hydrocarbons. It is therefore more probable that, in the formation of indigo from indoxyl, a carbon condensation between two molecules of the latter takes place. The constitution of indoxyl, as then regarded by Baeyer, was represented by the following formula:



To obtain indigo, by condensation through the medium of oxidation, from indoxyl, the union must take place at the second carbon atom from the benzene-ring, since the first carbon binds merely an hydroxyl-group. The hydrocarbon corresponding to such a union, Baeyer concluded, would be

$$C_6H_5C \equiv C—C \equiv C.\ C_6H_5,$$

that is, Glaser's diacetenylphenyl. To test this view, first the *o*-nitro-compound of the substance must be prepared. Direct nitration does not produce the desired result. *o*-Nitrophenylacetylene was therefore chosen as synthetic material. Numer-

1. Baeyer: *I. Ueber d. Verb. d. Indigogruppe*, Ber. d. deutsch. chem. Ges. *14*, 1741.

ous ineffectual attempts to unite two molecules of the mono-acetylene compound,

$$C_6H_5\left\langle\begin{array}{l}\overset{1}{C}\equiv CH\\ \overset{2}{N}O_2,\end{array}\right.$$

to one molecule of *dinitrodiphenyldiacetylene*,

$$C_6H_4\left\langle\begin{array}{l}\overset{1}{C}\equiv C-C\equiv\overset{1}{C}\\ \overset{2}{N}O_2 \qquad O_2\overset{2}{N}\end{array}\right\rangle C_6H_4$$

were made. This, notwithstanding, was finally accomplished by oxidation of the copper compound by alkaline solution of potassium ferricyanide. According to the mode of formation, it would be constituted as shown by the formula just given. The double occurrence in this combination of atoms of the group,

$$C_6H_4\left\langle\begin{array}{l}C\equiv C-\\ NO_2,\end{array}\right.$$

which makes its appearance in the formula of *o*-nitrophenylpropiolic acid once, naturally suggested the probability of the formation of *di*isatogen by the action of concentrated sulphuric acid in analogy with the formation of isatogen from *o*-nitrophenylpropiolic acid under the influence of the same re-agent. This actually proved to be the case. In the words of Baeyer: "This substance claims great interest as being of all artificially prepared substances the one which stands nearest to indigo and is most readily converted into the coloring matter." Simply moistened with ammonium hydrosulphide, it is immediately transformed into indigo, and that quantitatively. The process is further a direct one, the substance instantly becoming blue upon contact with reducing agents without dissolving and without change of form. From the formation of indigo from *o*-nitrophenylacetylene, it appears, therefore, that the production from indoxyl is a double transformation consisting, first, in that the second carbon atoms (from the benzene-ring) of two

molecules undergo a condensation with the elimination of two atoms of hydrogen, and, in the second place, the body thus formed is converted into indigo by further oxidation. The existence in the indigo molecule of the atomic grouping,

$$C_6H_4\left\langle\begin{array}{l}\overset{1}{C}—C—C—\overset{1}{C}\\ \overset{2}{N}\qquad\qquad\quad\;\overset{2}{N}\end{array}\right\rangle C_6H_4$$

was thus experimentally established wonderfully confirming Baeyer's deductions based upon the relation of indoxyl to indigo and the complicated structure of the latter. On account of the intrinsic interest of the subject and intimate relation of the compound to indigo, it will be in place to consider further the observations which have led to a knowledge of the constitution of *isatogen.*[1] It was found that when isatogenic ethylester is reduced in aqueous solution with ferrous salts, that an ester, $C_{11}H_{11}NO_4$, is produced. This same substance is obtained by the gentle and cautious oxidation of indoxylic ethylester. The new substance, indoxanthinic ethylester, is converted by more vigorous oxidizers, suchas chromic acid, into ethyloxalylanthranilic acid,

$$C_6H_4\left\langle\begin{array}{l}\overset{1}{C}O_2H\\ \overset{2}{N}H.CO.CO_2.C_2H_5,\end{array}\right.$$

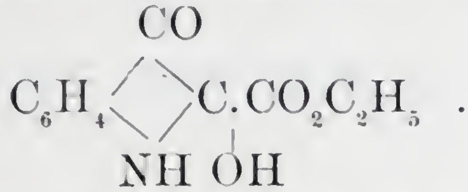
and is moreover readily reconverted by reduction into indoxylic ethylester, $C_{11}H_{11}NO_3$, which differ thus from indoxanthinic ethylester by one atom oxygen. The action of nitrous acid upon the latter produces a nitrosamine, an evidence of the presence in the molecule of the imido-group. Assuming for indoxylic ethylester the constitution,

$$C_6H_4\left\langle\begin{array}{c}COH\\ NH\end{array}\right\rangle C.CO_2C_2H_5,$$

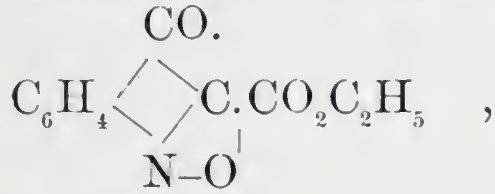
and in view of its close relationship to this compound, the form-

1. Baeyer: *II. Ueber d. Verb. d. Indigograppe,* Ber. d. deutsch. chem. Ges., *15*, 775.

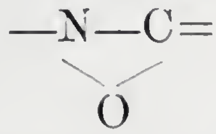
ation of a nitrosamine and the oxidation to ethyloxalylanthranilic acid, the formula of indoxanthinic ethylester would be



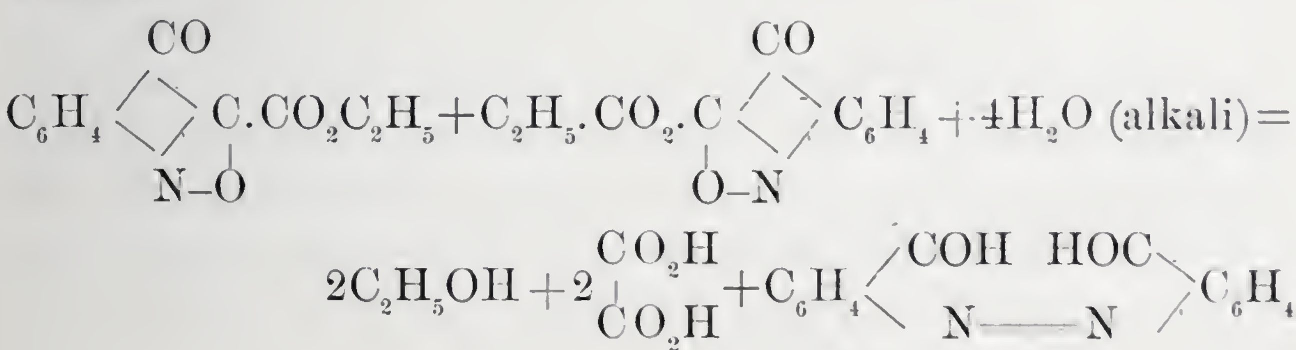
As already stated, the ester is derived by exceedingly cautious reduction of isatogenic ethylester. Representing this body by the formula



the transition to indoxanthinic ethylester is simply and perfectly explained: the bond between the oxygen and nitrogen atom is dissolved, and, by the addition of two atoms of hydrogen, the oxygen is changed to hydroxyl and the nitrogen to the imido-group as readily seen to be possible by a comparison of the formulas. The characterizing supposition is that of the existence of the atomic complex,



in the isatogen molecule. This is further in perfect accord with the fact that by the action of alkali *azo*benzoic[1] acid is formed:



Azobenzaldehyde.

Under the influence of alkali, the aldehyde (two mols.) becomes, according to a general reaction, azobenzylalcohol,

 and

1. The reactions are not given in detail in the original.

azobenzoic acid,

$$C_6H_4\left\langle\begin{array}{l}CO_2H\\ N\end{array}\right.\begin{array}{c}\\ =\end{array}\left.\begin{array}{r}HO_2C\\ N\end{array}\right\rangle C_6H_4 \quad ,$$

by the addition of two molecules of water. In a similar manner, from indoxanthinic ethylester, *amido*benzoic acid is produced:

$$C_6H_4\left\langle\begin{array}{c}CO\\ \\ NH\end{array}\right\rangle \begin{array}{l}C.CO_2C_2H_5\\ |\\ OH\end{array} + 2HO_2 \text{ (alkali)}=$$

$$C_6H_4\left\langle\begin{array}{l}\overset{1}{C}OH\\ \overset{2}{N}H_2\end{array}\right. + \begin{array}{c}CO_2H\\ |\\ CO_2H\end{array} + C_2H_5OH \quad ,$$

with the intermediate formation thus of *o*-amidobenzaldehyde. This, as before, yields a corresponding acid and alcohol:

$$2C_6H_4\left\langle\begin{array}{l}\overset{1}{C}HO\\ \overset{2}{N}H_2\end{array}\right. + H_2O \text{ (alkali)} = \underset{o\text{-Amidobenzoic acid.}}{C_6H_4\left\langle\begin{array}{l}\overset{1}{C}O_2H\\ \overset{2}{N}H_2\end{array}\right.} + \underset{o\text{-Amidobenzylalcohol.}}{C_6H_4\left\langle\begin{array}{l}\overset{1}{C}H_2OH\\ \overset{2}{N}H_2\end{array}\right.}$$

To *di*isatogen should therefore be ascribed the formula,

$$C_6H_4\left\langle\begin{array}{c}CO\\ \\ N-O\end{array}\right\rangle\begin{array}{c}C-C\\ |\quad\ |\end{array}\left\langle\begin{array}{c}CO\\ \\ O-N\end{array}\right\rangle C_6H_4$$

Of the remaining atoms of the indigo molecule, two each of hydrogen and oxygen, and the question as to the former's combination with nitrogen still require consideration and disposition. They have been fixed in their relationships to the others by researches which discovered the constitution of indoxylic acid and its derivatives. Of the latter the oximes or isonitroso-compounds, and of isatine as well, are of first importance. The study of the reactions of indoxyl with the aldehydes and ketone acids, with isatine and ethylpseudoisatine threw additional light upon the subject, and incidentally discovered the chromophoric group of indigo; they furthermore

strongly corroberated the evidence adduced by the investigation of the nitrous acid derivatives of indoxyl and isatine.

If in indoxylic acid (ester), which is transformed by gentle oxidation into indigo, the position of the oxygen be established and the question as to the existence of the imido-group in its molecule be answered, the positions of the extra-benzene hydrogens and the two oxygen atoms in indigo are likewise as definitely determined. The constitution of indoxylic acid (ester) as assumed by Baeyer immediately after his earlier investigation of the subject was

$$C_6H_4 \left\langle \begin{matrix} COH \\ N \end{matrix} \right\rangle CH.CO_2H$$

It will be recalled that the acid was formed from indoxylic ethylester which in turn was obtained by reduction of isatogenic ethylester. As already pointed out in another connection, indoxylic ethylester becomes by gentle oxidation indoxanthinic ethylester. In consideration of all pertinent circumstances, the formula of this substance can only be

$$C_6H_4 \left\langle \begin{matrix} CO \\ NH \end{matrix} \right\rangle C(OH).CO_2C_2H_5$$

The presence of the imido-group, which is an essential feature, is demonstrated by the formation of a *nitrosamine*. Reduction of indoxanthinic ester forms indoxylic ester in which the presence of the imido-group must likewise be assumed, it being highly improbable that in the reduction the imido-hydrogen of the indoxanthinic ester should be removed[1]. The formula of indoxylic ester should therefore be

$$C_6H_4 \left\langle \begin{matrix} COH \\ NH \end{matrix} \right\rangle C.CO_2C_2H_5$$

and not as first published. The presence of the imido-groups and a corresponding position of the oxygen atoms in indigo may be presumed with a like degree of certainty.

1. Baeyer: II. *Uber d. Verbindungen d. Indigogruppe, V.;* Ber. d. deutsch. chem Ges. 15, 775.

In his extended research upon the nitrous acid derivatives of indoxyl and isatine, Baeyer found that these bodies react according to two formulas, those representing them in the free state, and other isomeric combinations designated pseudo-forms and corresponding to certain derivatives conceived as generated from the first by the migration of an hydrogen atom. The pseudoforms exist only as derivatives. The formulas below will explain the distinction :

$$\underset{\text{Indoxyl.}}{C_6H_4\left\langle\begin{matrix}COH\\NH\end{matrix}\right\rangle CH,}\qquad \underset{\text{Pseudoindoxyl.}}{C_6H_4\left\langle\begin{matrix}CO\\NH\end{matrix}\right\rangle CH_2,}$$

$$\underset{\text{Isatine.}}{C_6H_4\left\langle\begin{matrix}CO\\N\end{matrix}\right\rangle C.\,OH,}\qquad \underset{\text{Pseudoisatine.}}{C_6H_4\left\langle\begin{matrix}CO\\NH\end{matrix}\right\rangle CO}$$

Among the derivatives of these combinations, *isonitrosopseudoindoxyl or pseudoisatine-α-oxime*,

$$C_6H_4\left\langle\begin{matrix}CO\\NH\end{matrix}\right\rangle C{:}NOH$$

is of great interest from its still more direct bearing upon the question of the position of the oxygen atoms and the existence of the imido-groups. The compound is produced by the action of nitrous acid upon ethylindoxylic acid,

$$C_6H_4\left\langle\begin{matrix}C(O.\,C_2H_5)\\NH\end{matrix}\right\rangle C.CO_2H+NO_2H=$$

$$CO_2+C_2H_5OH+C_6H_4\left\langle\begin{matrix}CO\\NH\end{matrix}\right\rangle C{:}NOH.$$

I.

Water may be regarded as being added, forming

$$C_6H_4\left\langle\begin{matrix}C(OH)(O.C_2H_5)\\NH\text{ ——— }\end{matrix}\right\rangle CH.CO_2H.$$

The splitting off of alcohol and carbonic anhydride would leave

$$C_6H_4\left\langle\begin{matrix}CO\\NH\end{matrix}\right\rangle CH_2,$$

which with nitrous acid gives the isonitroso-compound. That

a body of the given composition (I.) and not of two other possible configurations results,

$$C_6H_4\left\langle\begin{array}{c}COH\\NH\end{array}\right\rangle C.NO \text{ or } C_6H_4\left\langle\begin{array}{c}CO\\NH\end{array}\right\rangle C\left\langle\begin{array}{c}H\\NO\end{array}\right. ,$$

II   III.

was demonstrated by the behavior of the ethylation product obtained by the use of one molecule of ethyliodide and sodium alcoholate. In the first place, the derivative by reduction and subsequent oxidation yields isatine and not ethyl(pseudo)isatine,

$$\begin{array}{ccc} & CO & \\ C_6H_4 & \lt\gt & CO \\ & N.C_2H_5 & \end{array} ,$$

showing thus the ethyl-group not to have substituted hydrogen in the imido-group, but, if formula I. be correct, in the hydroxyl of the isonitroso-group. Formula II. would require substitution in the hydroxyl and a compound unstable to boiling acid; the substance on the contrary resists decomposition by boiling concentrated hydrochloric acid. If III. be assumed, the ethylation must have taken place on the carbon atom binding the nitroso-group, a supposition inconsistent with the easy transformation, by the successive processes of reduction and oxidation, into isatine. Of the three discussed expressions for the substance,

$$C_6H_4\left\langle\begin{array}{c}CO\\NH\end{array}\right\rangle C.N(OC_2H_5)$$

is most in accord with its behavior. By further action of the sodium alcoholate and ethyliodide (one mol. each), one[1] more ethyl-group was introduced. The resulting compound, its mode of formation, its analysis, its resistance to alkalies and even boiling acids considered, must be constituted as indicated by the formula below :

$$\begin{array}{ccc} & CO & \\ C_6H_4 & \lt\gt & C{:}N(O.C_2H_5) \\ & N.C_2H_5 & \end{array}$$

1. Baeyer: IV. *Ueber d. Verbindungen d. Indigogruppe, V;* Ber. d. deutsch chem. Ges. 16, 2188.

This compound, *ethylpseudoisatine-α-ethyloxime*, was converted by Baeyer by very gentle reduction into *diethyl*indigo. Oxidation of this compound produces ethylpseudoisatine.

$$C_6H_4\left\langle\begin{array}{c} CO \\ \\ N.C_2H_5 \end{array}\right\rangle CO$$

This reaction together with the process of formation furnishes indubitable evidence that the ethyl-groups of diethylindigo are bound by nitrogen. Confirmative of these observations and in analogy with the first, *pseudoisatine-α-oxime*,

$$C_6H_4\left\langle\begin{array}{c} CO \\ NH \end{array}\right\rangle C{:}NOH$$

by the same agency produces *indigo*. By these remarkable experiments, the existence of the imido-groups in the indigo molecule was established, and the position of the oxygen atoms given beyond reasonable doubt.

As confirming the conclusion with reference to the disposition of the oxygen atoms, Baeyer directs attention to the fact that the moderate reduction of isatine chloride,

$$C_6H_4\left\langle\begin{array}{c} CO \\ \\ N \end{array}\right\rangle C.Cl$$

and ethylisatine,

$$C_6H_4\left\langle\begin{array}{c} CO \\ \\ N \end{array}\right\rangle C\,(OC_2H_5),$$

both bodies of the indigo-group, which contain oxygen combined with the carbon atom next to the benzene-ring, and only such, produce indigo.

From still another stand-point, the question as to the constitution of indigo has been illuminated. Baeyer observed that mixtures of aqueous solutions of *indoxyl with certain aldehydes* give rise to stable red precipitates, accompanied by the formation of one molecule of water. *p*-Nitrobenzaldehyde, to take a simple instance, undergoes a similar reaction. Indoxyl

and nitrous acid likewise produce a yellowish red precipitate, also with the separation of one molecule of water. These phenomena, it was concluded, were of themselves sufficient evidence for the assumption of similarity of constitution. The conclusion, however, became unquestionable when it was discovered that both (the nitrous acid derivative after substitution of the hydrogen of the oxime-group by ethyl) form with sodium alcoholate blue salts whose solutions in chloroform *show the spectrum of indigo.* The nitrous acid derivative is the already discussed pseudoisatine-α-oxime,

$$C_6H_4\Big\langle\begin{matrix}CO\\NH\end{matrix}\Big\rangle C{:}NOH \quad ,$$

By analogy the compound from p-nitrobenzaldehyde would be

$$C_6H_4\Big\langle\begin{matrix}CO\\NH\end{matrix}\Big\rangle C{:}\overset{1}{C}H.C_6H_4.\overset{4}{N}O_2 \ .$$

Such bodies Baeyer denominated *indogenides*, and the dyad atomic complex

$$C_6H_4\Big\langle\begin{matrix}CO\\NH\end{matrix}\Big\rangle C\Big\langle \quad ,$$

contained by them all, *indogen.* Its substitution in place of oxygen in the simple aldehydes (acetaldehyde, benzaldehyde), and others by application in aqueous solution produces *yellow* crystalline unstable substances. When derived from other more complicated aldehydes (p-nitrobenzaldehyde, terephthalic aldehyde), and also benzaldehyde (with indoxyl in dry condition) *red* stable precipitates are obtained. With *ethylpseudoisatine,*

$$\begin{array}{c} CO \\ C_6H_4\Big\langle\quad\Big\rangle CO \\ N.C_2H_5 \end{array}$$

an indogenide remarkably resembling indigo in properties is formed. Finally the synthesis of indigo from pseudoisatine-α-oxime, whose constitution has had detailed consideration, discovers indigo itself as *di*ïndogen,

$$C_6H_4\Big\langle\begin{matrix}CO\\NH\end{matrix}\Big\rangle C{=}C\Big\langle\begin{matrix}CO\\NH\end{matrix}\Big\rangle C_6H_4 \ .$$

Throughout these reactions, the chromophoric character of indogen is fully exhibited. Colorific properties are generated by its substition in intrinsically colorless substances, and these increasingly as the complexity of the substituted compound increases. At the beginning of the series, there is the *yellow* and unstable indogenide from acetaldehyde, and, in its culmination, the exceedingly stable and intensely *blue* indigo.

Thus, by cumulative evidence gathered from divergent lines of investigation with wonderful skill, the proposition around which these unique researches center is left upon an abundantly substantiated experimental basis.

III. Synthetic Indigo in Its Relation to the Vegetable Product.

Vegetable indigo is formed as a glucoside in the cells of plants of the genus *indigofera*, growing in India, Africa and Central America, in general, in a tropical climate: The Indian crops are of greatest importance both in point of quality and quantity. The seed of the plant is there sown in rudely tilled soil and harvested after a few months just before the blooming time. Two crops are grown each year. The coloring matter is secreted mainly by the leaves. To prepare it, the green plants are steeped in earthen ware or wooden vats in water and allowed to ferment during 9-15 hours according to the temperature. A yellow fluid is formed and run off into a vat, placed conveniently below the first. It is here agitated, to facilitate access of air for oxidation, mechanically or by hand. The fluid soon begins to change color to green and later blue with the gradual separation of the coloring matter as a blue precipitate. After clearing, the supernatant fluid is removed and the precipitate transferred to a third vessel where it is boiled with water for several hours to still fermentation and to some extent purify it. Collection upon filter-cloths, expressing the adhering water, forming by cutting into cubes or lumps, drying, and packing complete the preparation for the market.

Vegetable indigo is not the nearly pure substance represented by its rival, synthetic indigo, but besides contains indirubine, indigo-brown, glutinous substance, ash, and other impurities derived from the mode of preparation. In the adulterated color, chalk, lime, ashes and the like are found. The percentage of indigo may vary from 20-90 per cent.

The Indian indigo crop for each year from 1879 to the present time is given in the table[1] below :—

Year.	Factory Maunds.
1879	73,128
1880	136,200
1881	135,405
1882	150,278
1883	159,388
1884	166,507
1885	108,692
1886	131,261
1887	130,825
1888	132,354
1889	144,718
1890	100,733
1891	150,506
1892	87,231
1893	116,329
1894	160,400
1895	162,200
1896	158,800
1897	110,212
1898	124,580

The yield for 1898 was 124,580 maunds or 11,012,872 lbs., in value, at the average price[2] of 64c. for that year, nearly $7,050,000. Allowing that the Indian production is five-eighths of the total and that of other growers proportionally good at the price given the value of the total yield for 1898 would be about $11,275,000[3].

1. *Amer Wool and Cotton Reporter*, Oct. 12, 1899, p. 1209. By the courtesy of Messrs Kuttroff, Pickhardt & Co., New York, my attention has been directed to this and other statistical information here reproduced. I am further indebted to the same firm for samples of artificial indigo used in illustration of the lecture.

2. Journ. Soc. Dyers and Colorists : *Indigo Chart*, Oct., 1898.

3. Otto N. Witt (*Prometheus*, xi, 371) estimates the value of world's production of indigo at $15,000,000.

In competition for this prize, the leading representative of Germany's chemical industry, the great Badische Anilin-u. Sodafabrik, has entered with synthetic indigo by processes described or modifications of them. It may not be amiss, particularly at the present juncture in its development, to pause for a moment's consideration of the magnitude of this industrial giant.[1] Its products are chiefly the coal-tar colors of every class embracing the aniline, alizarine, azo, resorcine, and gallic acid coloring matters. It further manufactures every variety of auxiliary and intermediate product consumed in the above preparations, including all products of the acid, soda and chlorine industry. It was founded in 1865 and is now situated in Ludwigshafen on the Rhine, opposite Mannheim, one of the most influential commercial centers of Southern Germany, and has branch works in France and Russia. The main concern at Ludwigshafen employs 100 scientifically trained chemists, 30 engineers and a commercial and accountant force of 230 men. In 1896, including overseers and laborers, the employees of the works numbered about 4800. The factories occupy 210 acres of which 60 acres are covered by buildings of the works, and 492 dwellings for laborers and 78 for officials. Within its limits, there are 21 miles of railway. The consumption of coal yearly is 190,000 tons. For the generation of steam for the heating of apparatus and running 190 steam-engines of 6500 horse-power, there are 83 boilers. The water-works of the establishment provide annually 2,640 million gallons of water, an ice plant supplies over 13,000 tons of ice, and the gas-works generate nearly 340 million cubic feet of gas. For electric lighting, there are four dynamo-machines of 1,000 horse-power supplying current for 6,400 incandescent lights and 470 arc-lights. There are nearly three acres of shops for repairs of every description and the construction of special apparatus.

This establishment owns the principal and promising

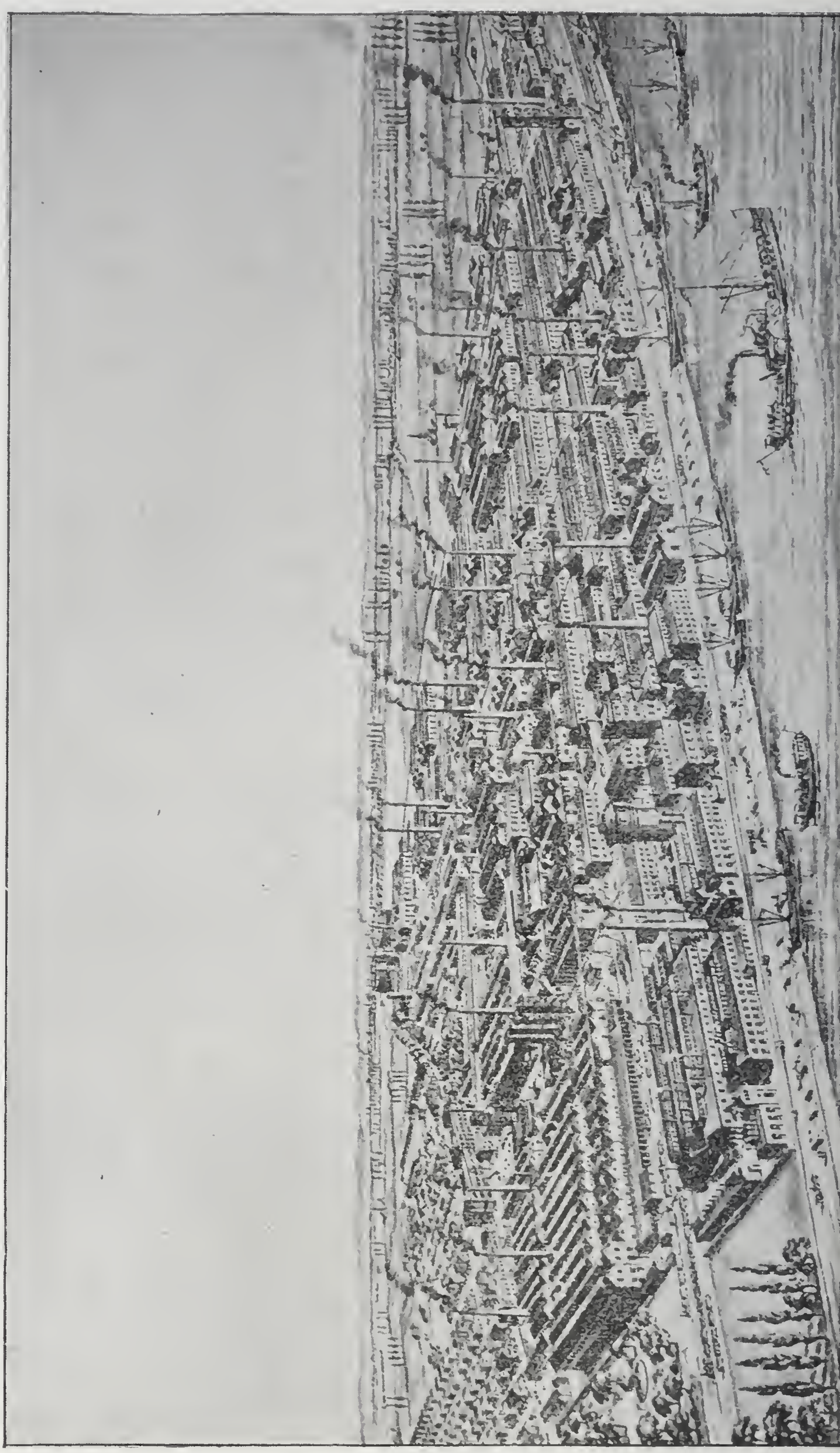
1. The data are from 1896.

patents relating to artificial indigo and intermediate products required in its preparation. In connection with investigators already named, it has, since Baeyer's *o*-nitrocinnamic acid synthesis, almost incessantly worked upon the problem of rendering methods discussed practicable. Experiments, in the main, have been directed toward a cheapening of the necessary materials and intermediate products. After a period of twenty years, difficulties have been so far overcome that synthetic indigo is an established article of trade, making its appearance somewhat generally first in 1897. Already it is making itself felt by a material reduction in the price of indigo. In April, 1880, the year of Baeyer's first promising synthesis, medium quality of Bengal indigo sold for $1.87 per pound; in December, 1898, one year after the introduction of synthetic indigo, at 87c. Good medium Kurpah brought 90c in January, 1890, and only 62c in December, 1898, in the London market. In September of last year the synthetic preparation was quoted at 38c in New York.[1]

When Woehler discovered a synthesis for urea, nearly seventy-five years ago, the tilling of a fertile field in chemical research was begun. One by one, a long list of compounds, in Woehler's time generally regarded as exclusively within the creative power of the vital force resident in the cells of vegetable and animal organisms, has become a proud trophy of searching investigation.

The knowledge acquired by these triumphs over mystery as connected with the animal organism has acted with beneficence upon the development of higher physiology and the science of medicine. By the synthesis of alizarine and indigo, the vegetable world has been invaded with results already prominently presented in the first instance, and those of similar significance are now confidently regarded as fast approaching a brilliant industrial climax for synthetic indigo.

1. *Oil Paint and Drug Reporter*, Sept., 1899.



Badische Anilin u. Sodafabrik, Ludwigshafen, a. Rhein.

Indigo Plant (*Indigofera Tinctoria.*)

Preparation of Vegetable Indigo.

PROF. ADOLPH V. BAEYER.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two-hundred and fourth regular meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture Room of the Society's House, 410 Penn Avenue, Pittsburg, Pa., Tuesday evening, April 17th, 1900, thirty-six members and visitors being present. The meeting was called to order at 8:30 o'clock by the President, Mr. W. A. Bole.

The minutes of the preceding meeting were read and approved.

For the Board of Direction, the following applicants were reported as passed and to be voted for at the next regular meeting.

CHARLES H. DAVIS, - -	Consulting Engineer, 99 Cedar Street, New York City.
EDWIN H. HASLAM, - -	Superintendent, Pressed Steel Car Co., McCandless Avenue Works, Allegheny, Pa.; 417 Denniston Avenue, East End, Pittsburg, Pa.

The following gentlemen were balloted for and duly elected to membership:

WM. H. BAILEY, - - -	Draughtsman, With Thos. Carlin's Son's Company, Allegheny, Pa.; Coraopolis, Pa.
GEORGE J. BRYEN, - -	Master Mechanic, Duquesne Blast Furnace and Steel Works, Duquesne, Pa.
ARTHUR B. CAPEN, - -	Pittsburg Agent Of The Babcock & Wilcox Co., of New York; Hotel Schenly, Pittsburg, Pa.
WILFRED D. CHESTER, -	Salesman, With the Babcock & Wilcox Co., 235 McKee Place, Pittsburg, Pa.

WM. H. LEDGER, - - - Engineer,
Keystone Bridge Works, Pittsburg, Pa.

ALEX. W. PATTON, - - Engineer,
Pittsburg Coal Co., 232 Fifth Avenue, Pittsburg, Pa.

For the Program Committee, Mr. Albree reported that he found it very difficult to get papers, as the members were all too busy to devote the time required to write a paper.

For the Library Committee, Mr. Hirsch reported that they had added a Catalogue Department to the Library, and that the members would find on file the latest trade catalogues of the most prominent manufacturers.

The Financial Committee reported that they were getting out a circular letter asking for contributions to the new House Fund, and they trusted the members would act promptly.

The death of Mr. A. P. Tanner, a member, was brought to the attention of the Society, and it was voted that the President appoint a committee to draw up a suitable memorial on his death.

Next in order was the reading of the paper of the evening by Mr. J. D. Lyon, entitled "The Gas Engine in Practical Use."

It was voted that the thanks of the Society be tendered to Mr. Lyon for the paper.

On motion, the Society adjourned at 9:40 P. M.

REGINALD A. FESSENDEN,
Secretary.

THE GAS ENGINE IN PRACTICAL USE.

BY J. D. LYON.

The gas engine as a real factor in the production of power came into existence less than thirty years ago, when the genius of Otto applied to a practical machine the conditions laid down by Beau de Rochas fourteen years earlier.

Earlier attempts to transform the heat energy of rapidly burning gases into kinetic energy by allowing them to expand behind a piston were not entire failures, but as is now well known, compression before ignition was the chief novelty in Otto's engine which secured its success.

The cycle of Beau de Rochas and Otto is too well known to require a detailed description, and its theory has been very thoroughly worked out in the works of Clerk, Robinson, Witz and others.

Early compression gas engines were almost exclusively of the "slide valve" type, with open flame ignition. Figure 1 illustrates this type of gas engine. The improvements made since the time of the slide valve engine have been very marked, but the principle upon which the latest designs operate is exactly the same as that of the first compressing engine.

The manufacture of the gas engine was commenced in America soon after the Centennial Exposition in 1876, where it was first exhibited in this country. The introduction here was much more difficult than in Europe, no doubt owing to the relatively low cost of coal in the United States. Small sizes only were constructed at first, and by degrees a demand was created for them for a great variety of uses.

The price of illuminating gas was the greatest obstacle in the way of their introduction, being in many cases as high as $2.00 per 1,000 cubic feet. The gas consumption of a slide

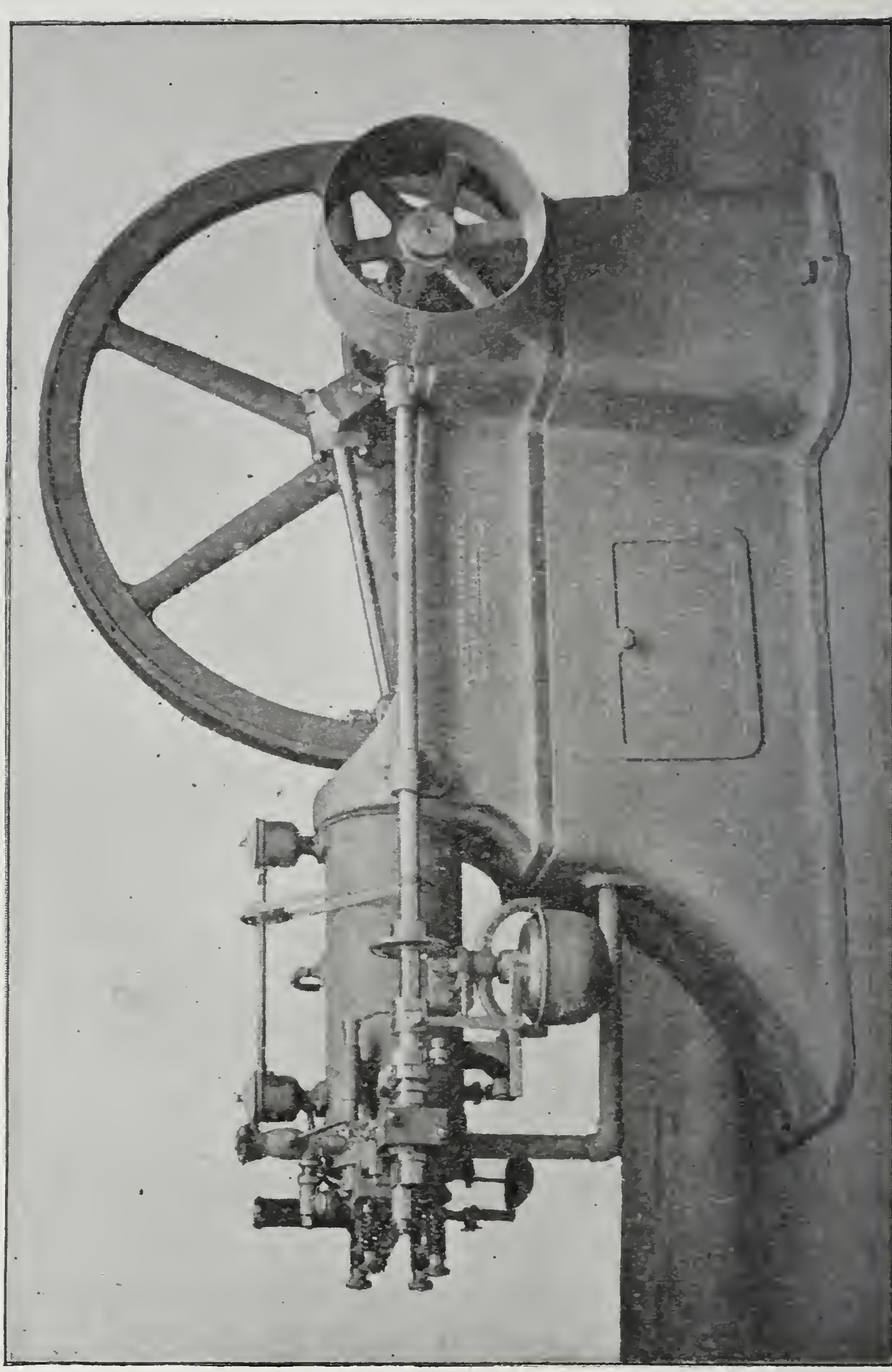


Fig. 1.

valve gas engine of 15 horse power was about 22 cubic feet per B. H. P. hour, exclusive of the small lighting flame.

The efficiency of such an engine would thus be nearly 18 per cent. if the gas ignited in the engine is alone considered. This is much higher than steam, even in large capacity, but the costs of equal calorific values in gas and coal show a large balance in favor of the coal.

Several thousands of these engines were put in use in this country before their final abandonment in favor of the poppet valve engine, the largest size being, I believe, about 25 horse power.

These engines were applied to almost every conceivable work for which small power is required, but in such work as operating printing presses, small shops, pumps and elevators, was found their field of greatest usefulness. It is interesting to note that even in this stage the gas engine had become a factor of considerable importance in many industries, although it had in a large number of cases replaced hand power only.

In our interest in the results obtained with large gas engines we are likely to forget the greater aggregate value of the small engines now scattered over the country in great numbers.

Some time ago the "Gas World" published the following: "It is said that the distribution of 2,323 gas engines throughout thirty-six representative German cities is as follows, the cities ranging in population (1890) from 3,000 to 348,000, with an average of 68,000:

Printing and Lithography	14.4	per cent.
Pumping	8.6	"
Textile	7.9	"
Electric Lighting	7.6	"
Machine Shops	5.3	"
Joiners and Cabinet Makers	5.0	"
Butchers and Sausage Makers	5.0	"
Locksmiths	4.2	"
Coffee Roasters	3.1	"
Cutlery	2.9	"
Elevators	1 6	"

"The remaining 34.4 per cent. is scattered throughout 140 more industries. This would seem to prove that the gas engine is the motor of small industries; but it must be borne in mind that Germany is the land of small industries."

I am not aware of the date upon which these figures were accurate, but I should say that an investigation of an equal number of installations in this country at the present time will show quite as wide a range of work.

Reasons other than economy of fuel frequently lead to the use of the gas engine, among them being the small amount of attendance required in operating it. This one point is mentioned for the reason that while it has been responsible for the purchase of many gas engines, an exaggerated value placed upon it has been a prolific source of trouble.

Lack of intelligent attention is responsible for more unsatisfactory gas engines than all other causes combined. Because the gas engine will run with little attention it seems unreasonable to some owners to think that its bearings will cut when run without oil for only a half hour or so, or that failure to turn the water into the water jacket at starting should prove disastrous.

However, some real knowledge of the gas engine is now to be found among the engine room attendants, and troubles of the character mentioned are becoming fewer. Further, in justice to many gas engine owners it is well to say that they have been in some cases misled, unintentionally, by salesmen failing to impress upon them the importance of careful systematic attendance.

It is probable that the origin of some of the prejudices existing against the gas engine to-day can be traced to the peculiar difficulties encountered in the use of the slide valve engine. It was in comparison with the modern poppet valve, electric igniter engine, both sensitive and capricious, although in the hands of a man who understood it, the results obtained were good. Slide valve engines never proved successful to

any extent with natural gas. That they were good engines however is proven by the fact that many are still in operation on illuminating gas.

With the introduction of the poppet valve and a better form of igniter the compression of the charge of gas and air was greatly increased, the result being higher mean effective pressures, which, combined with the higher speeds made possible by the change, increased the power obtained from a cylinder of given size, and rendered the construction of larger engines less difficult. The consumption of fuel was also decreased, and at the same time the use of new and cheaper fuels became a possibility.

The principal gas engine fuels are as follows: the order in which they are named indicating in my opinion their relative importance in the vicinity of Pittsburg: (1) Natural gas. (2) Blast furnace gas. (3) Producer gas. (4) Illuminating gas. (5) Gasoline.

Natural gas being of high calorific value, cheap and well distributed becomes an almost ideal gas engine fuel, and one with which it can compete against the steam plant even when fuel cost alone is considered.

With natural gas of about 1,000 B. T. U. per cubic feet I have obtained one B. H. P. hour with less than 12 cubic feet, on test with a 20 horse power gas engine. As this gas varies considerably in calorific value, it is not safe to assume that this economy can be expected in practice. With a Junker's calorimeter I have found a variation of from 925 to 1137 B. T. U. per cubic feet in the gas in Pittsburg and Allegheny. 1,000 B. T. U. per cubic feet is the value usually assumed, and it is reasonably near the average. Assuming 13 cubic feet per B. H. P. hour, the engine efficiency shown will be very little under 20 per cent.

Nearly all gas engines in the vicinity of Pittsburg are employing natural gas, and this will probably continue as long as the supply holds out and prices remain reasonable.

In the list of gas engine fuel blast furnace gas is ranked as second in importance, although its application must of necessity be limited to a small number of installations, but of large capacity. It will be readily seen that the gas engine using this gas could never assume the position of general importance it now holds with natural gas. It has been ranked as second because of the probable effect in the future upon some of our largest local industries which are centered about the blast furnaces.

I do not know of any gas engine installations in this country as yet arranged for the utilization of the blast furnace gases, but in Europe the progress has been so great that it can only be a question of time until the practice has extended to this country. At present the largest gas engines in the world are using this fuel.

The two photographic reproductions Nos. 2 and 3 show the types of engines adopted by the Gasmotorenfabrik-Deutz for blast furnáce gases. This concern was founded by the late Dr. Otto himself.and it has always held a leading place in all gas engine development. In the use of this fuel the value of compression previous to ignition is well illustrated, as the gases containing so low a percentage of combustible that they will hardly burn with certainty under a boiler ignite with reliability in the cylinder of the gas engine, when compressed to say 110 lbs. per square cubic inch.

The fear that the fine metallic dust carried by the blast furnace gas would prove an insurmountable obstacle in the way of their use, has not proven well grounded. Scrubbers of the simplest character eliminate this dust to such a degree that the small amount remaining, passes out of the cylinder harmlessly with the exhaust gases. In one instance a small experimental engine ran 16 hours per day for four months without cleaning.

Mr. Wilhelm Spiecker, commercial director of the Gasmotorenfabrik-Deutz, when in this country a few months ago informed me that the most careful measurements upon blast

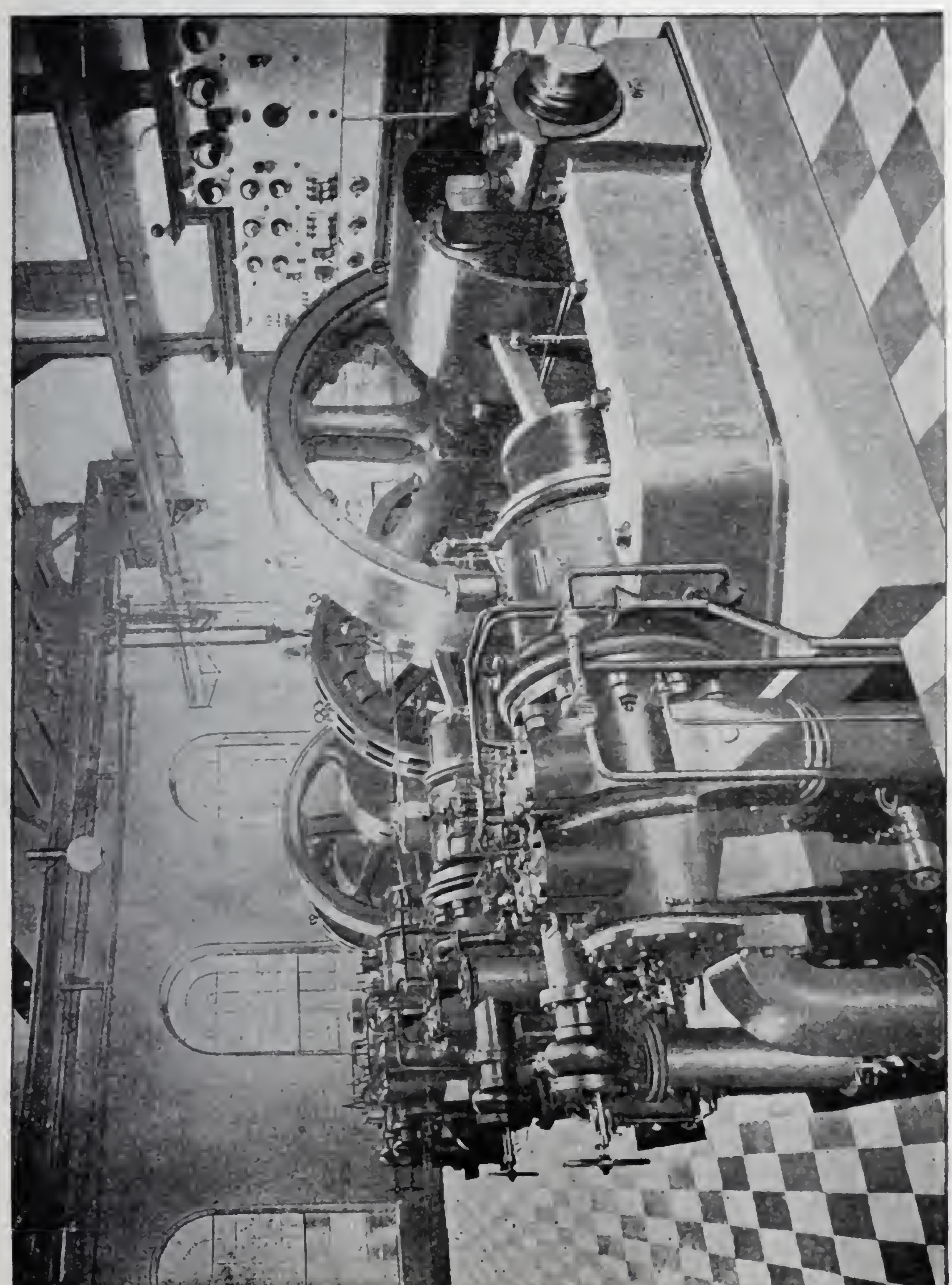


FIG. 2.

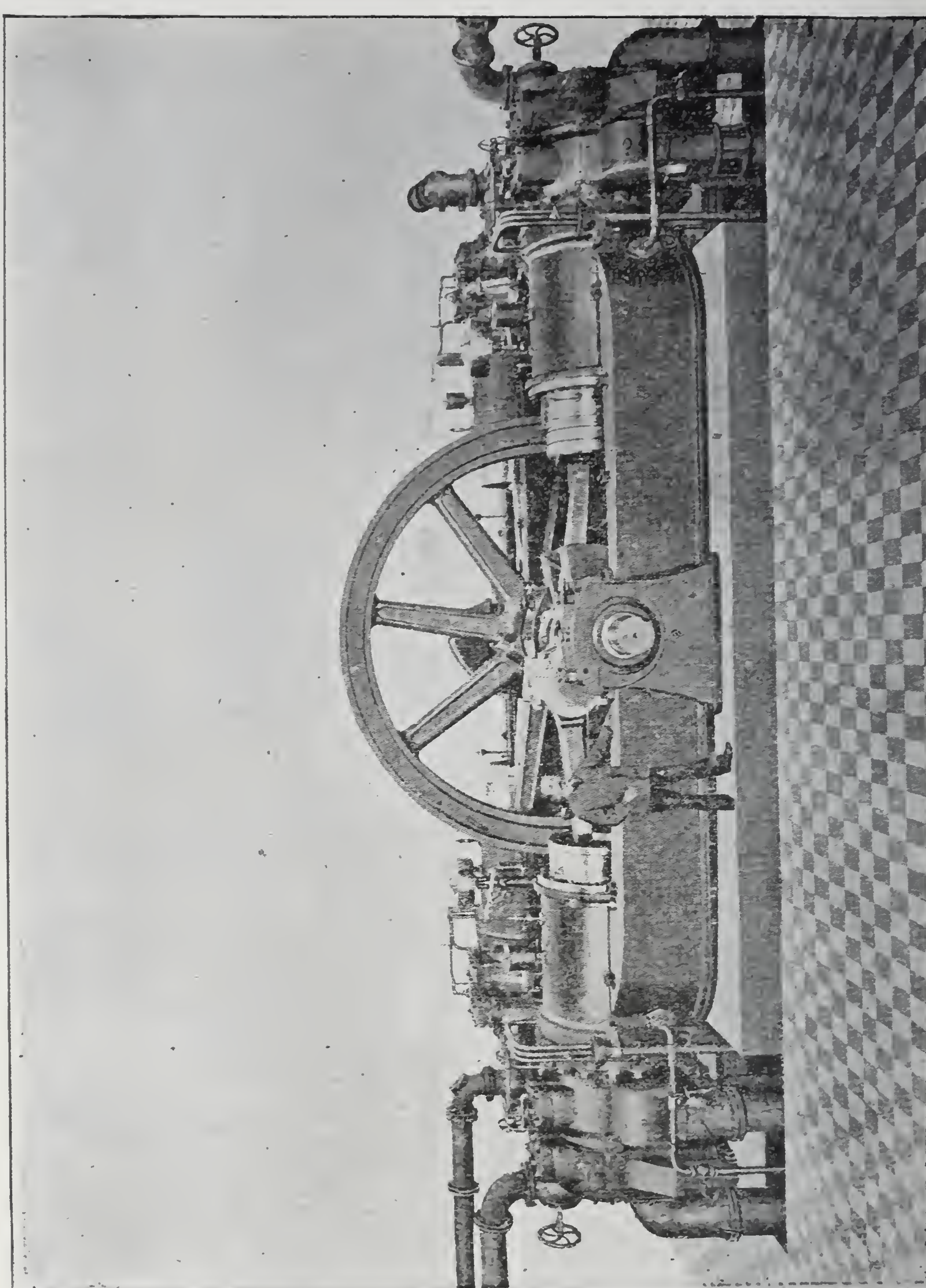


Fig. 3.

furnace gas engines after several months service fail to show any undue or exceptional wear upon the cylinders or pistons.

That this new branch of gas engine development has passed successfully its experimental stage is evident from the rapidity with which European blast furnace managers are placing orders for large sizes.

The company just mentioned had up to last fall booked orders for about twelve thousand horse power in addition to a number of plants already installed. Among the largest plants are those at Oberhausen, and the Duedelingen Iron Works, Luxemburg. The former consists of one 600 horse power and two 300 horse power units, all double cylinder. The latter plant consists of two 1000 horse power and one 500 horse power unit.

The largest single cylinder gas engine ever built has been in operation in Belgium since last September, as a blowing engine. The cylinder of this engine is 51.1″ by 54.1″. An excellent description of this engine and its performance will be found in the "Engineer" of recent date.

With the benefit of foreign experience, and the assurance given by precedent, it would seem that great strides should be made in this most economical method of utilizing that portion of the blast furnace gases devoted to the production of power. Nearly five times as much of this gas fired under a boiler is required to produce a given power as would be required in a gas engine, thus leaving after the performance of the present work, a large surplus for other purposes. By electrical transmission, this power may be conveniently delivered at any desired point within a reasonable distance with very slight loss.

The average calorific of blast furnace gas is about 100 B. T. U. per cubic feet, and its consumption in the gas engine varies from 95 to 115 cubic feet per B. H. P. hour.

Passing on to the next fuel, producer gas, I will say that I believe this is to be to a great extent the final solution of the gas engine fuel problem, as far as the general use of large

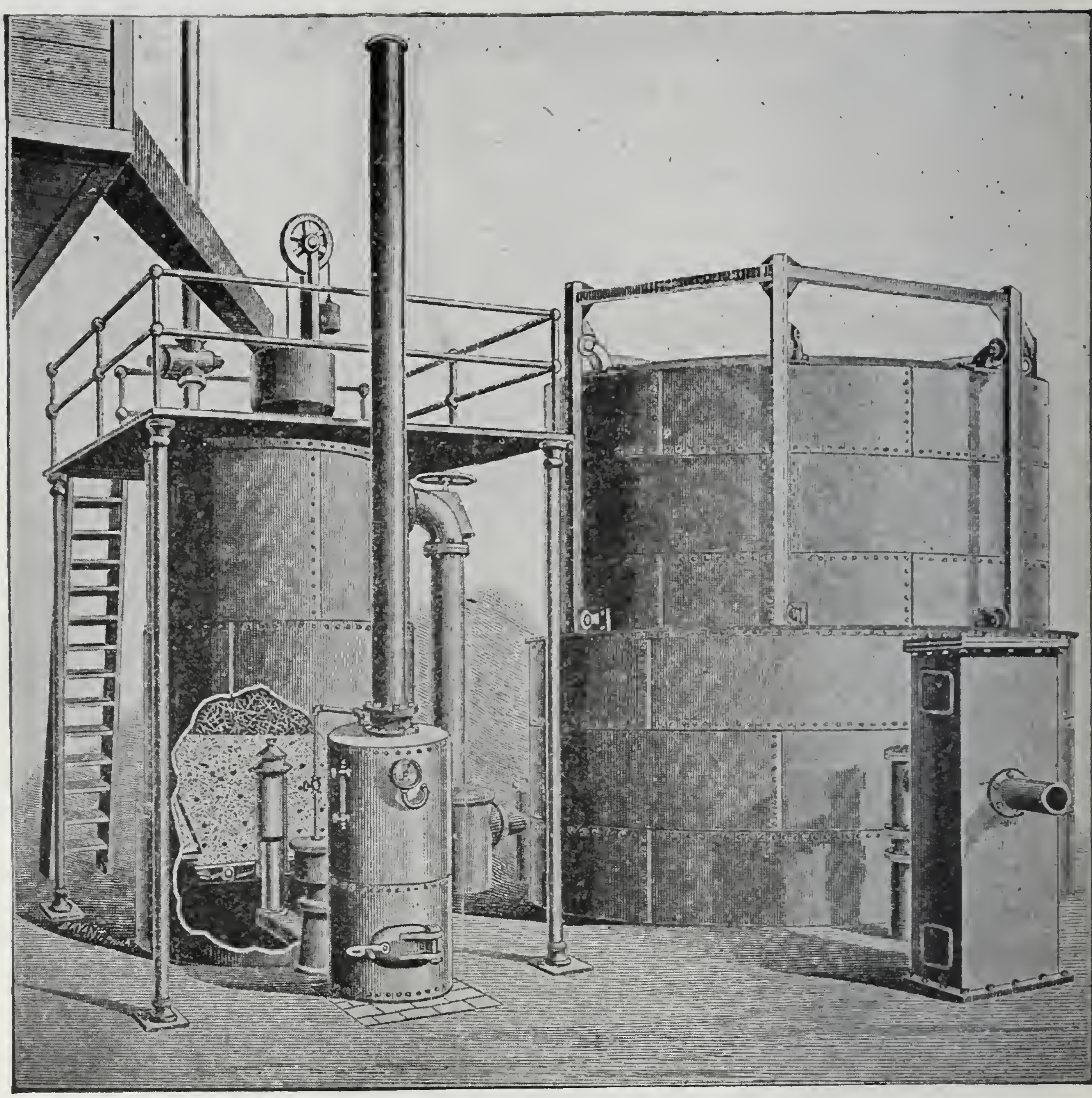


Fig. 4.

engines is concerned. Already several plants are in operation in this country and many in Europe with efficiencies higher than the best steam plants.

Seven years ago a test by Prof. Spangler (see Journal of the Franklin Institute, May, 1893) showed a consumption of 1.3 lbs. of coal per B. H. P. hour in a producer furnishing fuel for a 100 horse power "Otto" gas engine. This result has since been improved upon until an economy of a little over 1 lb. per B. H. P. has been attained. Up to this time anthracite coal and coke are the only fuels available in the producer for gas engine service, since an unwarranted expense is necessitated to produce a fixed gas from bituminous coal. It is probable that bituminous producers will be made in the future at a cost which will warrant their installation. When such a time arrives, the gas engine and producer will be purchased exactly as the steam engine and boiler of the present, but with the assurance of far higher efficiency, consequently lower fuel cost, lower cost of attendance, and greater safety. One pound of good anthracite coal will make about 90 cubic feet of gas, having a calorific value of about 137 B. T. U. per cubic feet.

Prominent examples of the use of gas engines with producer gas are the Danbury, Connecticut 300 horse power, and the Erie R. R., Jersey City, 425 horse power plants.

To show the general arrangement of a producer for this purpose, I take the liberty of using an illustration (Figure 4) from the catalogue of Messrs R. D. Wood & Co., who have furnished the producers in the plants mentioned.

Illuminating gas comes next in the list of fuels, and as stated before, it is responsible for an enormous number of small engines and some of larger capacity scattered over the entire civilized world. While neither so special nor so localized as natural gas, illuminating gas for fuel requires that the user reside within a certain distance of the gas main. With the movement to reduce the price of fuel and power gas,

illuminating gas becomes more interesting as a possible fuel for large engines.

Cincinnati has had 50 cent gas for about one year, and according to the "Gas Engine," published in that city, many engines previously operated with gasoline are now run with gas, some 350 horse power being thus effected.

However, with gas at $1.00 per thousand cubic feet, the gas engine in large units can never compete with steam unless some peculiar local conditions render steam undesirable at any price.

In smaller units, the case is different owing to a disproportionate amount of skilled attendance required by the steam plant, and to a gas engine characteristic which will be mentioned later, namely the regulation of fuel to conform with the work done. Most small engine users have only intermittent use for their machines and greatly varying loads, both of which conditions would point to gas as the most desirable power, and probably the most economical even in fuel.

Gasoline, which is placed last in importance in this district favored with cheap gas, stands easily first over a large portion of the country. Its introduction as a gas engine fuel opened a new and wide field for the engine by making it available beyond the limits of city gas mains. Thousands of gasoline engines are in use upon the same wide variety of work as the gas engine, but with new uses added. In the northwest small gasoline engines are used by hundreds in the country grain elevators, and are popular in larger sizes in flouring mills and small water works for towns and villages. Several railroad companies have begun the replacing of steam tank pumping stations with gasoline engines. I have been informed that a single company has installed 35 from one manufacturer in the last year.

Small gasoline engines also find favor in the pumping of mines. It is plain that in such a case fuel cost is not the point considered. The facts that they can be placed almost anywhere

in the mine and do not require constant attendance, are greatly in their favor. Some astonishing savings are occasionally effected by the displacement of manual labor with the gasoline engine.

The total operating expenses of a small pumping plant in the Oak Station mine of the Pittsburg & Castle Shannon R. R. Co. for eight months, show a rate of saving which amounts to about $1,100.00 per year on an investment of less than $800.00. In this case a $3\frac{1}{2}$ horse power engine and directly coupled triplex pump clears the mine of water in $1\frac{1}{4}$ hours work each day. Two men at $1.75 each were formerly required to do this work, working seven days in the week. No trouble is experienced with installations of this kind, if provision is made for the rapid carrying off of the exhaust gases to the open air, and if proper precautions are taken at all times in handling the gasoline. I believe the limit of quantity of gasoline allowed inside a mine should not exceed say from three to five gallons, which quantities would represent about 24 and 40 B. H. P. hours, respectively. The smaller quantity in most cases of clearing a single mine in this vicinity would do a day's pumping.

Assuming the fuel consumption of the gas engine at the quantities usually estimated, the cost of one B. H. P. hour with the various fuels would be as follows:

Natural gas, at 25c. per 1,000 cubic feet	0.325c.
Producer gas, 1.3 lbs. coal at $5.00 per ton	0.325c.
Illuminating gas, 650 B. T. U., per cubic feet; $1.00, per 1,000 cubic feet	1.7c.
Gasoline, $\frac{1}{8}$ gal. per hour at 12c	1.5c.
Steam, 5 lbs. of coal per B. H. P. hour. Coal $1.10 per ton	.275c.

This comparison showing the coal to be cheaper when fired under a good boiler in a plant of fair size is a misleading one when the actual plant in operation is considered.

If it were possible to operate gas and steam engines with the fuels named at the prices given, and at a condition of constant full load, the comparative results would be represented

with fair accuracy. Under conditions of practice in which there are considerable fluctations in loading and the average load is considerably below the maximum, the saving of fuel by reason of the lighter load will be very small in the steam engine.

With the gas engine the governor acts directly upon the fuel supply and the quantity of fuel used in performing an average work a for n hours will approximate $nc\ (f+a)$ in which "c"=fuel consumed per I. H. P. hour, and "f"=the friction load of the engine (or, I. H. P.—B. H. P.)

This is probably more nearly true of engines governing upon the "hit and miss" principle than in any other type since all impulses are exactly the same in power, and the thermal efficiency is the same. It is this valuable characteristic of the gas engine which causes operating expenses to be over, rather than under, estimated in many cases, as when the maximum load is known it naturally forms a basis of calculation.

Very large gas engines are now being made in this country, the largest of all in Pittsburg at the well known Westinghouse works, and we have recently become accustomed to speak familiarly of gas engine units and plants the size of which we should have considered extremely large a few years ago.

The installation of the gas engine in large industrial plants has so far been chiefly auxiliary, although numerous concerns using as much as 100 to 150 horse power are dependent solely upon it. Among the first large concerns, and the first of its kind to accept the gas engine as the most satisfactory solution of the power problem, is the Pennsylvania Malleable Co., of this city, in their new works at McKees Rocks.

The decision in favor of the gas engine was reached after careful consideration of the power needs of the works and a searching inquiry into results obtained from gas engines upon a large variety of work. The prime consideration of economy was found to be in favor of the gas engine; the reliability in a properly designed plant to be equal to steam, while convenience,

flexibility and low cost of attendance were all favorable to the gas engine.

The plant when finished is to consist of twelve engines of 60 horse power each. The first installation is of 360 horse power, 240 horse power more is to be added within a short time, and if found necessary the remaining 120 horse power will be placed. Figure 5 shows approximately the type of "Otto" engine employed.

The engines are arranged in pairs with cylinder heads about 6 feet apart leaving an aisle of convenient width for the attendant. Two line shafts are operated, one on either side of the engine room. Engines and all engine room machinery except pumps, are belted to friction clutches upon line shafts. For the pumps ordinary tight and loose pulleys are used. The machinery of this room consists of four generators, two blowers and the pumps to which reference has been made.

All machines rest upon concrete foundations built up from level of solid ground to the floor a distance of about nine feet. Floor stands for shafting also rest upon concrete piers.

The foundations under each opposite pair of engines are connected through, below the floor level, securing entire freedom from the rocking or vibration, which so frequently mars the effect of an otherwise admirable installation. Gas is supplied from an eight inch line carried over from the wall of the building to the center of the engine room, being supported by the roof trusses. Over the center line of each pair of engines is placed an eight inch by $2\frac{1}{2}$ inch cross tee, from which connection is made to the engine through a pressure regulator.

Water is supplied to the water jackets from an overhead tank into which water is pumped from wells.

The exhaust pipes are run horizontally until they extend beyond the foundation. They are then carried downward and after passing through two exhaust vessels are further carried horizontally under the floor to the side wall of the building along the inside of which they pass vertically through the roof.

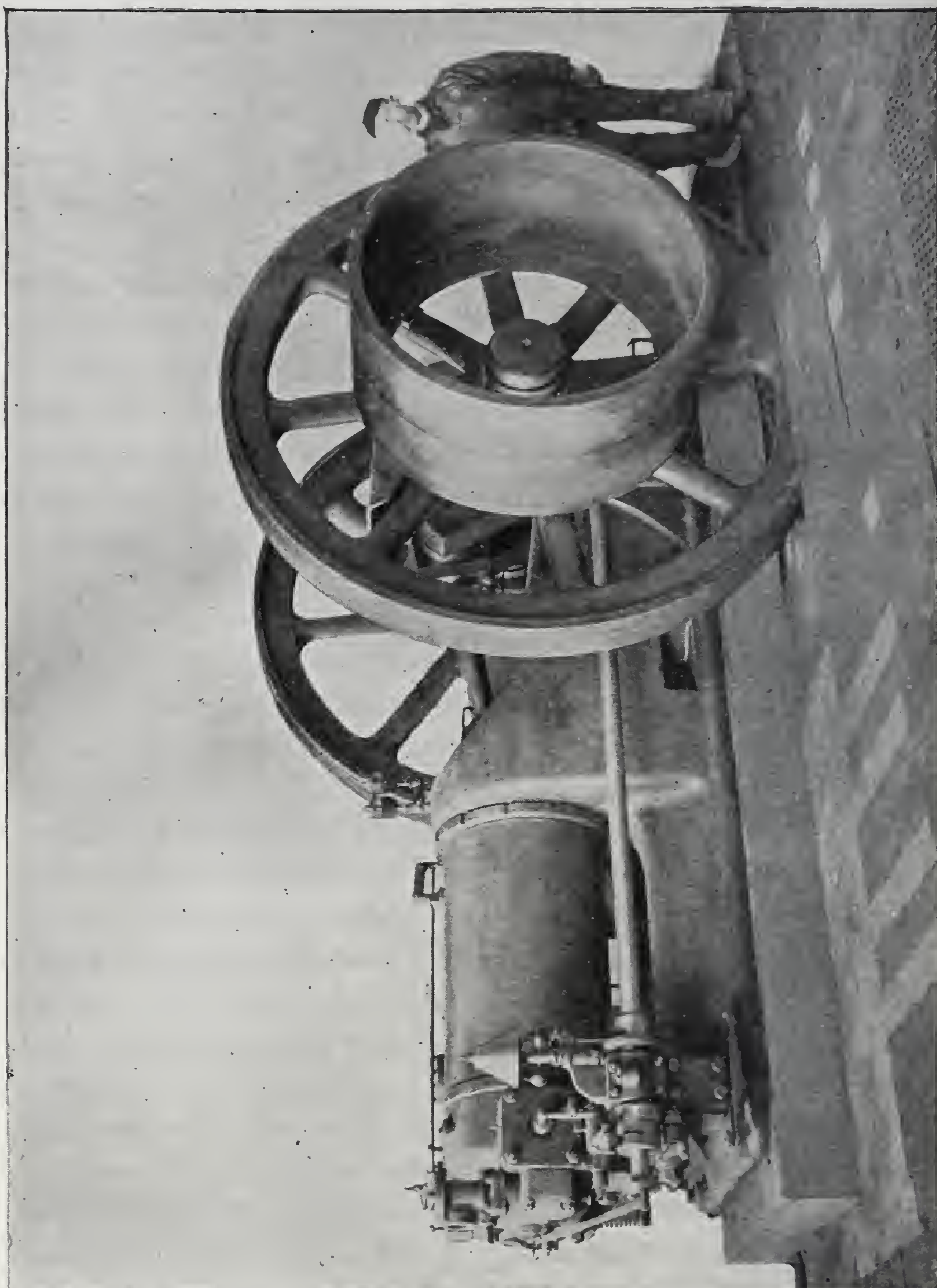


Fig. 5.

Power will be transmitted from the engine room by shafting for the machine shop, grinding and fitting department and the rolling room, estimated to require altogether 250 horse power. Blowers and pumps are estimated at 50 horse power. Twenty-five motors, having an aggregate capacity of 700 horse power, deliver power to the various departments. Among the purposes for which motors are employed are cranes, elevators, conveying systems, machine tools, etc.

While the total power required to operate all machines at maximum capacity at the same time amounts to over 1,000 horse power, it is considered perfectly safe to assume 700 horse power as the working maximum with all machines now installed or in contemplation at this time.

The periodic variations of load will be great, ranging from the power of a single pair of engines at night to a probable full load during the earlier and latter part of the day. This large fluctuation in load was the principal reason for the subdivision of the plant into such relatively small units.

No tests have yet been made upon the engines already installed, and as the entire plant is not in operation it is impossible to give the actual running cost.

The concern, being large users of natural gas for various purposes, secures the advantage of lower price for gas than the usual rate to consumers. Basing calculation on a gas consumption of 13 cubic feet of gas per B. H. P. hour, and a rate of 10 cents per 1,000 cubic feet, the cost of operating under full load of 700 horse power would be 91 cents per hour.

The most favorable conditions under which steam could be employed, with present prices of coal considered, can not equal this in economy.

The excellent arrangement of this department is due to the combined skill of Dr. R. G. Moldenke, Foundry Superintendent, and Mr. S. H. Stupakoff, General Superintendent of the Pennsylvania Malleable Co.

If the gratifying results obtained so far continue as more of the plant is put into service—and there can be no valid reason why they should not—the service it will do the gas engine will be of great importance.

Among other large local concerns in which the gas engine as auxiliary, and in one or two cases principal, power has been adopted, are The Oliver Iron & Steel Co., three engines, Baker Chain & Wagon Iron Co., Howard Axle Co., Zug & Co., Pittsburg Screw & Bolt Co., and many others. Several manufacturers of engines are represented in this short list.

Photograph 5 was taken from the larger of two engines furnished the Oliver Iron and Steel Co. It is a single cylinder engine developing 114 B. H. P. on illuminating gas of 650 B. T. U. per cubic foot.

It is interesting to compare this engine with its lineal prototype shown in Figure 1, as both were developed in the same shops, with a lapse of time of over twenty years.

Indications now point to a far greater development in the next twenty years, and unless some revolutionizing discovery in power production checks its growth, it seems inevitable that the gas engine will supersede steam, in moderate sizes at least.

MEETING OF THE CHEMICAL SECTION.

The regular monthly meeting of the Section was held at 410 Penn avenue, at 8:15 P. M.

Fifteen members and several visitors were present.

Mr. A. G McKenna read a paper on The Analyses of Chrome and Tungsten Steels. The paper was fully discussed by Messrs. Glass, Stahl, Harrison, Loeffler, Johnson, Handy, Mohr and others.

Mr. McKenna emphasized the importance of having a large excess of molybdate present when precipitating low phosphorus steels.

Mr. Johnson said that ignited molybdic acid gave more uniform results.

Dr. Harrison gave his method for determining graphite in pig iron.

It was the belief of the members that informal dinners before meetings of the Section were a pleasant feature and ought to be continued. Adjourned at 10:20 P. M.

G. O. Loeffler,
Secretary.

METHOD FOR GRAPHITE IN PIG IRON.

Contributed by Dr. A. B. Harrison, Chemist, Clinton Iron and Steel Co., Pittsburgh.

EGGERTZ'S METHOD (MODIFIED).

One gramme of drillings is dissolved in 100 c.c. of dilute HCl, when sample is "white" iron or iron high in combination carbon.

When sample is grey forge or foundry iron, use 100 c.c. of 1.13 sp. gr. nitric acid. When dissolved boil till all nitrous fumes are driven off; filter on tared papers. Place filters in separate funnels, filter through the filter on the left, passing the filtrate through the filter to the right; wash out the beaker with water, using wash bottle and detach any ad-

hering particles with policeman. Wash each paper several times with water alone, and then with acid and water alternately until free from iron salts. Then wash several times with water till papers are free from acid. Then wash the graphitic siliceous residue several times with hot dilute ammonia; wash papers free from dissolved carbons, using hot water. Finally wash with alcohol and then with ether; dry at 98 deg. C. and weigh. Burn the paper containing the graphitic residue in a platinum crucible: weigh the ash and subtract it from the difference in weight between papers. This leaves the weight of graphite which was burnt off. Calculate to per cent.

Papers should be dry, white and uniform in color, and should not be brittle. By tared paper is meant two papers which have been dried for 15 minutes in air bath at 98 deg. C. and have been carefully cut to equal weight. Example:

Difference in weight of paper	.0350
Weight of crucible and ash	23.3020
Weight of crucible	23.3015
Weight of ash	.0005

.0350 less .0005 equal .0345 weight of graphite equal 3.45 per cent.

REFERENCE: Cairn's Quantitative Chem. Analysis, p. 112-114, 1881 edition.

NOTE: Graphite, determined by the above method, checks well with the same determination by chronic and sulphuric combustion.

Combined carbon in pig iron when determined by color is usually somewhat low.

THE ANALYSIS OF CHROME AND TUNGSTEN STEELS.

BY A. G. M'KENNA.

The writer has had occasion during the past few years to make complete analysis on several hundred samples of steel, containing both chromium and tungsten, and has found the following methods very satisfactory, accurate results being obtained without excessive care or unusual precautions.

The steel is usually too hard to be drilled, and is broken up in a steel mortar until no single piece is larger than a grain of rice. For the determination of sulfur, silicon, tungsten, manganese and chrome, 5 grains are weighed into a 500 c.c. evolution flask, so arranged that the gases evolved on the addition of 30 cc hot water and 30 cc concentrated hydrochlori acid shall be absorbed by an ammoniacal cadmium chloride solution contained in a large test tube. The solution is made as rapidly as possible by the application of heat; as there seems to be evidence that with some irons lower results are obtained by the evolution method when cold acid is used. When the steel has dissolved the solution is boiled for a minute or two until no more hydrogen remains in the flask, being displaced by steam. The sulfur is then determined by titration with iodine in the usual manner, using starch solution as an indicator. By adding a few grains of zinc chloride to the starch solution it can be kept indefinitely without spoiling. The solution in the evolution flask is transferred to a 500 cc Erlenmeyer flask, 10 cc of strong HNO_3 added and evaporated to dryness on a hot plate, taken up with 15 c.c. strong HCl evaporated again to dryness, taken up in 20 cc strong HCl, diluted with hot water to about 100 cc, boiled and filtered. All the silica and tungstic acid will be on the filter paper; after washing thoroughly with a 5 per cent. HNO_3

solution the residue is ignited in a weighed platinum crucible $W_0O_3 + Si\ O_2$ and weighed. A few drops of HFl are now added and the crucible is heated to a bright red for five minutes to volatilize silica. The loss is silica which is calculated to silicon ; the residue in the crucible is tungstic acid, which is calculated to tungsten. This residue generally contains a trace of iron oxide which can be easily determined by fusing the residue, after weight has been taken, with sodium carbonate and filtering off the oxide of iron after solution in hot water.

The filtrate from the tungstic acid and silica is again transferred to an Erlenmeyer flask and evaporated to low bulk, 50 cc of concentrated HNO_3 are now added and the solution boiled until no more fumes come off, showing that all hydrochloric acid has been removed. Enough concentrated HNO_3 is added to make the volume 200 cc, and the solution again heated. When it has reached the boiling point, 10 grains of potassium chlorate are added and the solution boiled down to 75 cc in order to remove all chlorine.

The manganese will now be completely precipitated as MuO_2 and the chromium will be converted to chromic acid.

The solution is filtered on an asbestos plug while hot, and washed a few times with freshly boiled concentrated nitric acid. In the filtrate chromium is determined by titration with ferrous sulphate and permanganate according to the following reactions :

$$2\ Cr\ O_3 + 6\ Fe\ O = 3\ Fe_2O_3 + Cr_2O_3.$$

$$2\ K\ Mu\ O_4 + 10\ Fe\ O = K_2O + 2\ Mu\ O + 5\ Fe_2O_3.$$

If the solution is diluted to about 500 cc and cooled to about 20° centigrade before titration, there is not the slightest danger of interference by the nitric acid. The MuO_2 on the asbestos plug is dissolved by hot hydrochloric acid and a pinch of potassium nitrite. It is brought to a boil to drive off chlorine and the traces of iron precipitated by ammonia and ammonium acetate ; the basic precipitate is dissolved and reprecipitated to free from traces of manganese. In the filtrate

manganese is precipitated by bromine in a strongly ammoniacal solution, filtered, ignited and weighed as $Mn_3 O_4$——

For the determination of phosphorus, 5 grams is weighed into a porcelain dish and 60 cc of dilute nitric acid added. If the steel contains more than one per cent. of chromium it will probably be found necessary to add HCl from time to time to secure solution. Solution must be complete before allowing the evaporation to go too far, or it will be found almost impossible to dissolve the last particles of steel.

The solution is baked as usual in phosphorus determinations, 20 cc HCl added and again taken to dryness, taken up in 20 cc HCl again, diluted and filtered from tungsten and silicon, which may be ignited and weighed as a check on the first determination. To the hydrochloric acid solution 35 cc strong ammonia is added then sufficient strong nitric to redissolve the hydrate of iron. 100 cc molybdate solution, made according to Wood's formula as given by Blair, is added to the flask, which is then shaken for a few minutes to ensure complete precipitation of the phosphorus. After standing for an hour the yellow precipitate is filtered on a dried weighed paper, washed with dilute 1 per cent. nitric acid, dried for an hour and weighed as phospho molybdate, containing 1.63 per cent. phosphorus.

For carbon, 1.5 grams are dissolved in 100 c.c. of a 33 per cent. copper and potassium chloride solution. After standing half an hour 5 cc HCl is added to hasten solution. When all the precipitated copper has redissolved the solution is filtered through ignited asbestos in a platinum filter tube using suction to hasten filtration. The carbon on the plug is washed a few times with hot water then dried and burnt in a platinum tube with a stream of oxygen. The CO_2 is absorbed as $Ba\ CO_3$ in a barium hydrate solution contained in a ten bulb absorption tube, filtered, washed well with freshly boiled distilled water, ignited and weighed as $Ba\ CO_3$ containing 6.09 per cent. carbon.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

The two-hundred and fifth regular meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture Room of the Society's House, 410 Penn Avenue, Pittsburg, Pa., May 15th, 1900, twenty-seven members and visitors being present. The meeting was called to order at 8:25 o'clock, the President, Mr. W. A. Bole, being in the chair.

The minutes of the previous meeting were read and approved.

For the Board of Directors the following applicants were reported as passed and to be voted for at the next regular meeting :

HARRISON W. CRAVER, -	Reference Assistant in Technical Science. Carnegie Library, Pittsburg, Pa.
ROBERT C. FALCONER. -	Assistant Engineer, Penna. Co., Pittsburg, Pa.
ARTHUR B. JONES, - -	Manager, Versailles Works of The Baker & Adamson Chemical Co., Versailles, Pa.
KRISTIAN AUGUST JUTHE, -	Superintendent, Pittsburg Screw & Bolt Co., 326 Princeton Place, E. E.
HEW CHARLES TORRANCE, -	Manager, Pittsburg Office of the Brown Hoisting & Conveying Machine Co., 1112 Carnegie Building, Pittsburg, Pa.

The following gentlemen were balloted for and duly elected to membership :

CHARLES H. DAVIS, - -	Consulting Engineer, 99 Cedar Street, New York City.
EDWIN H. HASLAM, - -	Superintendent, McCandless Avenue Works, Allegheny, Pa.; 417 Dennison Avenue, E. E., Pittsburg, Pa.

Mr. Bole—It may be remembered that several months ago we sent out requests to our past presidents of the Society to favor the Society with their photographs to adorn the walls of the Society's rooms. That business is unfinished, inasmuch as only a few have complied with the request. I see the faces of past presidents here to-night whose pictures should adorn the walls.

It becomes a pleasure as well as a duty to present to you the photograph of one of the most illustrious of our past presidents, Mr. Emil Swensson

It was voted that the thanks of the Society be tendered Mr. Swensson for his picture and the frame.

Mr. Davison—What room is that picture to adorn?

Mr. Bole—I think the persons who send their pictures in first are to have the best places on the walls.

Mr. Johnson—Before we leave this subject I would like to say that one of the past presidents asked me recently about the size of the picture that was requested. I mislaid the circular that was sent out, so I did not know the dimensions specified in the request.

The secretary was requested to find out the size the pictures should be, and reported that in order to correspond in size to the other pictures, they should be about 15 by 18 inches.

Mr. Davison—While we are still on this subject, I would suggest that the gentlemen who intend to produce their pictures, have their signature on them also. Of course there will come a time when the gentlemen's faces will have been forgotten, but their signatures will serve as a constant reminder of them.

Next in order was the report of the committees.

Mr. Davison reported for the Building Fund Committee, that the amount of money sent in to date is about $500. There has been no special effort made to get subscriptions yet and I think this is a very good start. I notice a number of gentlemen here to-night who have not subscribed. I hope they will do so before they leave the house. It is going to be much

more expensive to get into this thing after awhile than it is at present. If they want to get in on the ground floor, they had better get at it at once.

The report of the committee on the death of Mr. Adams Tanner was then read:

MEMORIAL ON DEATH OF MR. ADAMS TANNER.

It is with regret that we announce the death of one of the younger members of the Society, Mr. Adams Tanner.

Mr. Tanner was the son of the late Judge Thomas Tanner, of Sharon, Pa. He graduated from the Case School of Applied Science, in Cleveland, in 1897. He entered the office of Mr. Julian Kennedy in the fall of the same year and remained in his employ until his death. His record in college and his brief term of experience as an engineer gave undoubted assurance of his success. He contracted typhoid fever in Pittsburg and died at the home of his mother in Sharon, on April 1st, 1900, at the age of twenty-three years.

A. Gow.
Julian Kennedy.
Victor Beutner.

It was moved and seconded that the report be received and printed. (Carried.)

The paper of the evening, by Chester B. Albree, entitled "An Inertia Valve Percussive Tool," was then read by the author.

AN INERTIA VALVE PERCUSSIVE TOOL.

BY CHESTER B. ALBREE.

In the last few years the use of compressed air as a motive power for machinery, has wonderfully increased, especially for portable tools. This is mainly due to the advantageous qualities of compressed air over steam, the principal of which are:

First. Stability, or in other words, non-condensention, permitting it to be stored indefinitely, or to be transported long distances without loss of pressure, other than that due to leakage and friction of the conduit.

Second. Low temperature at which it can be used in hand tools. Such tools could be run by steam, but they would become so hot that a man could not hold them in the naked hand.

Third. The exhaust consists of fresh cool air, adding to the ventilation and comfort of the workroom or mine, whereas the exhaust from steam motors has to be disposed of outside, and is a nuisance, and with hydraulic systems, the waste water must be carried away in pipes.

Fourth. It can be used at any pressure and is easily produced, and its expansive qualities, while not on a par with steam, owing to the absence of heat, yet can be utilized with good results, a feature entirely absent in hydraulic systems.

Against these advantages are opposed some few disadvantages, such as the losses of power in the compression of air, due to the absorption of energy in the generation of heat, and the subsequent loss of pressure in the compressed air, as it cools down to the temperature of the surrounding atmosphere. The losses of the steam end of the compressor are similar to those of any steam engine, and are well known to all of you.

The absorption of heat from surrounding media, caused by the sudden expansion of compressed air, often to such an extent as to freeze any moisture in the air or immediate neighborhood, will often prevent the use of high pressure air expansively unless the air be reheated. This reheating of compressed air can be done at very small fuel cost for the benefits attained, and is used in many places.

These points, however, are well understood, and compressed air is used intelligently.

With these few reminders of the qualities of compressed air, the subject of its application to percussive tools comes up, which can be better understood by prefacing with an outline of the development of percussive engines of different types, followed by a description of the inertia valve type which is the subject of this paper, and a discussion of some of the theroretical and engineering features involved in its design.

Percussive force, as regards the actual work done upon the object struck, is applied in two ways:

First. Directly, when the tool itself is propelled through space and strikes the object, when practically all of the energy of the moving mass is expended on the object struck. The commonest examples are the hand hammer, sledge, steam hammers, rock drills, mining stamps and others of similar character.

Second. Indirectly, when the moving mass strikes an interposed tool, through which the energy is transferred to the object.

In this case a portion of the energy is consumed in overcoming the inertia of the interposed tool: the remainder only performing useful work on the object. The energy thus consumed in overcoming the inertia of the interposed tool, supposing the energy of percussive force to be constant, varies, by well known laws, according to the weight or mass of the interposed body. The mathematical discussion of inertia is out of place in this paper, but those interested in the subject, can find full

discussion of it in Weisbach's, Rankine's and other works on applied mechanics.

Examples of this second type of application of percussive force, are the mason striking his stationary chisel, the quarryman's drill struck by the sledge, and the chisel struck by the piston of a pneumatic hammer.

After hand hammers, which have been used from time immemorial, perhaps the lifting of a weight, and subsequent dropping it, was the first step in advance, and one which is still in daily use in drilling oil wells and driving piles.

Trip hammers of crude form, were in use as early as 1600, and before them, spring catapults were used to throw great stones against castle walls. In a manner, these may be classed as hammers of the first type, as the projectile certainly struck a blow, as do those of our great modern rifles, with a little more force.

Nasmyth's steam hammer, invented in the early forties, was a great step forward, and undoubtedly led to the invention of the rock drill, although as far back as 1683 a drill of the oil well type was used for rock, but only vertical holes could be drilled.

In 1844, one Brunton, suggested compressed air in a cylinder as a convenient means of working a hammer to hit a drill, and in 1859, Nasmyth, who was a wonderful engineer, at a meeting of the British Association for the Advancement of Science, suggested that the loss of energy in overcoming the inertia of an interposed tool, could be overcome by lancing or projecting the tool itself against the work, and exhibited a sketch of an ingenious machine having a piston with a tool attached to the piston rod, working in a cylinder, closed at the lower end and open at the top, so arranged that when the piston was mechanically pulled to the back of the cylinder, a vacum would be created below it, and on releasing the piston, the atmospheric pressure would drive it down with a constantly increasing velocity. This device, he pointed out, could be

used to drill holes at any angle, as it was independent of gravity for its power.

October 15th, 1851, Cave, a Frenchman, patented a machine for rock drilling, run by compressed air, in which the valve was actuated by hand, and the drill rotated by hand. It was a double acting engine, and was successfully used, and was the pioneer rock drill in Europe.

Couch, an American, patented a rock drill in 1849 in which both the valve motion and the rotation of the drill were automatically performed by the piston in its motion, and while it was a cumbersome machine, requiring cranes to handle it, it was in its essential features, the rock drill of to-day.

Since that time, there have been wonderful improvements in detail, and numberless devices made for regulating and controlling the different parts, yet to America belongs the credit of the real development of the rock drill.

There are three methods of *automatically* controlling the admission of motive fluid in rock drills and other percussive engines.

FIRST. The tappet valve type, in which projections attached to the reciprocating part, strike triggers or other devices which in turn move the valve.

There are several objections to this type. The clearances are necessarily large, the liability to breakage is great, due to the intricacy and multiplicity of parts; the small variation of stroke permittable and the fact that the valve must be moved before the piston has completed its stroke.

This is a good feature on the back stroke, as it permits of forming a sure cushion preventing piston hitting back cylinder head, but on the front stroke it is bad, as it allows initial pressure air to bear against and partially check the velocity of the piston, hence weakening the possible blow.

Owing to the skill and care with which machines of this type are constructed, most excellent results have been and are now being accomplished with them, and such well known man-

ufacturers as the Ingersoll-Sargent and the Rand Rock Drill Companies, continue to sell them in large quantities.

SECOND. The fluid moved valve type, wherein the piston itself, at certain parts of its travel, admits a supply of motive fluid to move the valve or to move a supplementary piston which in turn moves the valve.

Such machines, if well made, are not liable to get out of order, but the stroke is subject to limitation within narrow range of length, and air is admitted before end of out stroke, as was described of the tappet valve type.

In neither type has there been much attempt to use the air expansively, as the decreased velocity due to decreasing pressure, and the additional mechanical complications, did not seem to warrant it.

The Optimus Drill, of English make, is an exception. It belongs to the fluid-moved valve type, using the motive fluid compound. The initial fluid driving the piston outward, is used expansively to effect the return stroke. It is much in use abroad, but has not met with much favor here.

THIRD. The so-called valveless type, in which the moving piston acts as its own valve, as in its stroke, it alternately opens and closes certain ports, so that the fluid acts on each end of the piston in turn.

The progenitor of this type was invented by John Darlington, May 13th, 1873, in England, and a great many were used, though now superseded by the modern drills of the first and second types described.

In this machine, the motive fluid acts constantly on the smaller area of the piston. When the piston is at the outer end of its stroke, the space in the rear is open to the atmosphere and the constant pressure on front area, forces the piston back. In its motion, it closes the exhaust port and a back cushion is started in the rear. At a certain distance before the motion of piston is entirely checked by the cushion, a by-pass leading from front to rear end of cylinder, is opened ; this

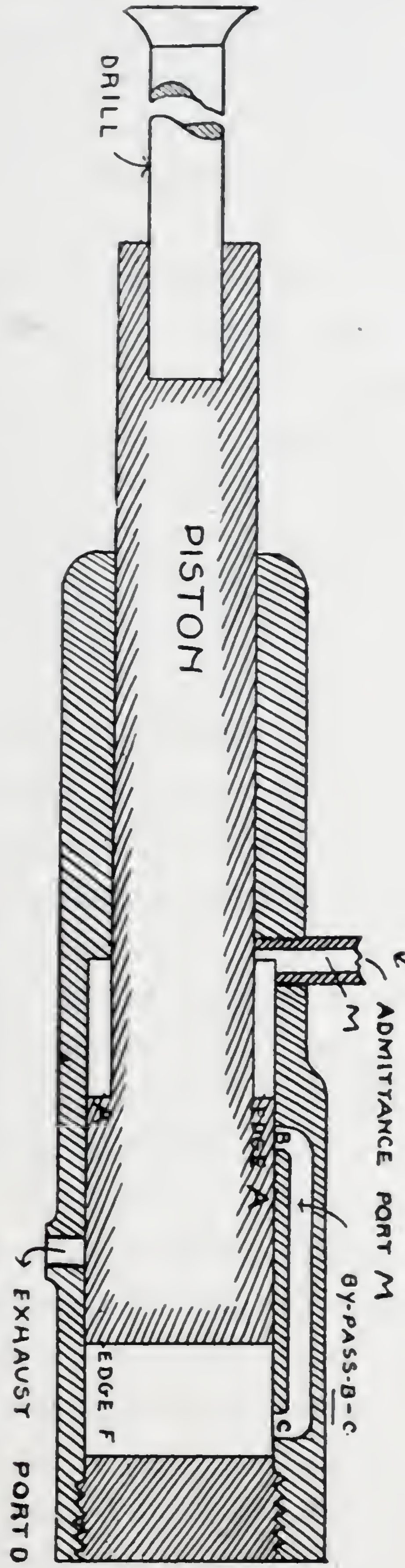

DRILL
PISTON
M
ADMITTANCE PORT M
EDGE A
BY-PASS-B-C.
EDGE F
EXHAUST PORT D

Fig. 1.

by-pass being a little longer than the main body of piston. Fluid rushes through this passage to the space in rear of piston, pressing on large diameter of same with initial pressure, drives piston forward against the pressure on small diameter, with a force due to the excess of area, under the same pressure per square inch. Very early in the down stroke, the by-pass is closed again by body of piston, and further force is derived only from the expansion of the body of high pressure fluid, locked in the rear of piston.

Against this decreasing pressure of expansion, is opposed the constant pressure on the small front area, so that the nett forward force is constantly decreasing, although sufficient, combined with the momentum already acquired, to propel piston its entire stroke with considerable velocity, utilized in effective work on the object struck by the tool. When nearly at end of out stroke, the exhaust in rear is again opened, so that further travel is entirely due to the acquired momentum. As soon as the blow is struck, the piston is stopped, and immediately is pushed back by pressure on front area and the operation repeats.

The conception is unique and beautiful, the drawback being the loss of velocity on the out stroke, as described.

The action of this tool has been explained in detail, as it was in the endeavor to overcome this defect, that experiments and study were made of the problem.

In Darlington's drill, the initial pressure was used for the back stroke, and the expansive force used for the out stroke. April 13th, 1880, Wm. L. Neill took out a U. S. patent for a valveless rock drill, reversing this action, so that the effective out stroke was due to initial pressure, and the return stroke to expansion. This device never was used practically, as far as can be ascertained, probably due to the fact that a cushion was formed in front of the piston, when the exhaust was closed, increasing in force as the piston progressed, and decreasing the velocity thereof.

Having thus examined the three principal types of valve motion in ordinary use, we come to the development of the Pneumatic Hammer, which consists essentially of a small portable cylinder in which a piston reciprocates very rapidly, striking a great number of blows per minute on the end of a tool inserted in the end of the cylinder.

It belongs to the second class of percussive tools, having a tool interposed between the hammer and the work.

McCoy may be said to be fairly entitled to the credit of the first application of such tools to heavy work, such as chipping metals, caulking boilers, cutting stone, &c., that had been done previously by hand and hammer. He exhibited his device before the Franklin Institute, which awarded him a medal for a new and meritorious invention of real utility.

He was not, however, the originator of the broad idea, as long before he perfected the tool for heavy work, it had been used as a dental plugger, a device working compressed air in a cylinder, so that a piston struck the end of a tamping tool, used to insert gold into the cavities in teeth.

There were several patents taken out for such tools and successful results attained in the 70's.

The pneumatic hammers followed in a general way, the valve motions used in rock drills, with modifications adapted to smaller and more portable tools. The valveless, as also tappet and fluid moved valve, types are used. Of the former, the Q. & C. tools are quite well known. For work within their range, they are admirable, owing to their simplicity of design, small size and great rapidity of short stroke blows. For light chipping, caulking and other similar work, they can hardly be excelled. A some what similar tool, the Kotten, is made for use in carving stone and marble, die sinking and other delicate work, and has a very short stroke, about $\frac{1}{4}''$ to $\frac{1}{2}''$, running as high as 10,000 or more strokes per minute.

For heavy chipping, rivetting and other work, the blow of a valveless tool is not heavy enough to do the work well,

and tools with a controlling valve are used, allowing of much longer stroke, and higher velocities of piston travel.

Of the fluid-moved valve type, the Boyer hammer, made by the Chicago Pneumatic Tool Co., and the Little Giant hammer, made by the Standard Pneumatic Tool Co., are the best known. In these, a small valve, located in a chamber in the rear of the piston, travelling parallel or right angles to the axis of the piston, is actuated by air pressing on differential areas, moving it alternately to and fro, opening and closing ports controlling the admission and exhaust to the cylinder. Suitably placed small ports are closed and opened by the piston in its travel, that permit air to act on and move this valve.

Excellent work is accomplished by these tools, and a skilled workman can do from four to six times as much as can be done by hand tools alone. They are in use in nearly all the progressive machine, boiler, bridge and ship works in this country, and in a great many abroad.

In driving rivets, greater force is required than in chipping. This can be attained in a pneumatic hammer in two ways: By larger mass in the piston, or by greater velocity.

The force of a blow varies directly as the mass or weight; and as the square of the velocity; hence a tool can be designed with a heavy piston and short stroke with high pressure, or the same result attained by larger cylinder diameter with lower pressure, but the better, and generally adopted method; is to increase the length of stroke, keeping the diameter small. This would follow theoretically as a result of the law given. There is again a practical reason why the diameter should be kept small, because the reaction would otherwise be too great. Since action and re-action are equal and in opposite directions, the total force used to propel the piston out, presses equally against the back cylinder head, and a man can withstand but a limited amount of such pressure when holding the tool, thus limiting the diameter to such size as has been found practicable.

To meet the demand for a long stroke tool, the Chicago

Pneumatic Tool Co. have put on the market, the "Long Stroke Boyer Hammer" having a piston about $1\frac{1}{2}$-in. diameter, with 9-in. stroke, striking a very hard blow, due to the continued application of a constant force through the long stroke, constantly accelerating the piston velocity. The valve is moved by tappets and at pressures of about 100 lbs. per square inch. $\frac{7}{8}$-in. rivets can be set down much quicker and about as tight as by hand, but the rivets do not fill the holes as well as those driven by compression riveters, driven by air, steam or hydraulic pressure, nor nearly so quickly. For the erection of structural work, or for any field riveting, it fills a long felt want, doing the work sufficiently well.

With this perhaps rather long examination of what has been accomplished in percussive tools, and study of the underlying principles, the subject of this paper, "An Inertia Valve Percussive Tool" will be discussed.

Recalling the Darlington Valveless Rock Drill and referring to the drawing (Fig. 1), we notice that when the rear edge F of the piston, passes exhaust port D on the back stroke, that a cushion is at once started in the rear, increasing in pressure as the piston travels back. When the front edge A of the piston passes and opens the entrance B of the by-pass B-C, initial pressure air flows through admittance port M, cylinder cavity and the by-pass to the rear of the piston, immediately checking any further movement and forcing the piston out by reason of the greater area of surface F over surface A. In such forward movement the edge A again closes the port B of by-pass, cutting off the supply of further initial pressure air to the rear, so that any additional pressure or force upon rear area of the piston, must be derived from the expansive action of the air locked in behind it, which, you will notice, is opposed by the initial pressure air bearing on surface A, which is constant at all points of stroke, either forward or back.

It seemed, on study of this device, that if some way could

be found to allow air of initial pressure to follow up the piston during its entire downward stroke, that much greater piston velocity would be secured.

To accomplish this result, it was obvious that an automatically moved valve of some sort, must control the flow of air, in such a way as to prevent any access to the rear during the back stroke, and to permit such access during the forward stroke.

The first solution that appeared was the use of a type of

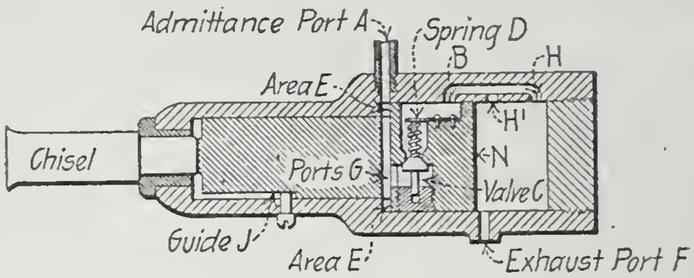


Fig. 2.

poppet valve, with a spring bearing upon it, so that when there was no pressure on one side, the valve would close under unbalanced pressure, but when the pressure was alike on each side, the spring would force it open.

To clearly understand it, referring to the print, A is a port admitting air continually against area E. G is a port leading from this area E to the valve chamber shown.

C is a valve with spring D bearing against the side of it that is away from the constant supply of initial pressure in port G, arranged so that pressure against it from port G will close it against pressure of spring, when no pressure exists back of it.

B is a by-pass having two outlets communicating with cylinder h & h^3. F is an exhaust port, adapted to be closed and opened by the rear edge of the piston. J is a guide to prevent piston from turning, as the device as shown required that the valve cavity should not come in contact with the exhaust port F.

In action, air enters through A, pressing against small area E closes valve G and forces the piston back, the space in the

rear of piston and in the by-pass and valve cavity having exhausted through port F.

When the piston travels so that the edge E passes port B, air at high pressure goes through by-pass to rear, and at the same time through the port h into the valve cavity, thus equalizing the pressure on the sides of valve C, which opens under the pressure of the spring D, permitting free passage of the air through port E, and the valve cavity port h and by-pass to the rear, forcing the piston out, owing to the excess area.

As it travels out, this passage, either through B or h is continually open, so that a continuous current of air flows through the valve at initial pressure until the exhaust port is opened at F, reducing the pressure in the rear when the valve again closes, and the action is repeated as described.

This seemed very nice on paper and worked fair to middling badly. When the spring C was exactly right in intensity for a given air pressure, it worked nicely, but any variation of pressure interfered with good results. Again the rush of air through the valve had a strong tendency to close it, requiring a superfine adjustment of the intensity of the spring.

For static pressures, the idea was all right, but for dynamic pressures, if one could so call air under pressure in motion, it was not all that could have been desired.

In the line of simplicity and experiment, a rearrangement of the parts was made, as shown in drawing.

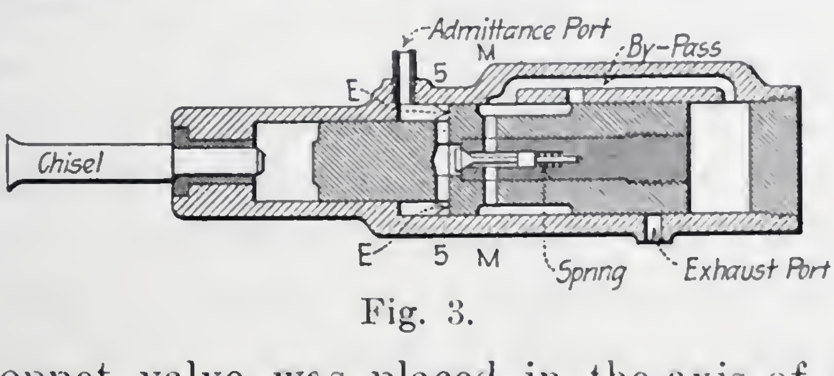


Fig. 3.

The poppet valve was placed in the axis of the piston, which did not then require guides to keep it from turning and the construction was simpler. Results somewhat better than in the first machine were attained, but it was discovered that the

inertia of the poppet valve interfered with the contemplated action of the device.

This movement of the valve by inertia, suggested the use of a form of slide valve that should be controlled entirely by inertia, opening and closing suitable ports in its travel to accomplish the desired ends.

A tool, as shown in the drawing, was designed, having an axial hole in the center, within which a small tube could move freely within fixed limits.

A constant supply of air is admitted at 4 against the small area of piston. Ports 5-5 lead from a point adjacent to this small area into valve chamber, which in turn opens to the rear end of piston.

An exhaust port, 14, leads through the cylinder and a groove around exterior of piston, communicates by a port 7 to the valve chamber.

In starting, the tubular valve is at the outer end of chamber, thus closing ports 5-5 and leaving ports 7-7 open.

Owing to the constant pressure on the small area, and the exhaustion of pressure in rear of piston, it travels back, and the rear edge closes exhaust port 14, which, however, registers at the same instant with annular groove on piston, establishing a new means of exhaust through the valve chamber, ports 7-7 and annular groove 8 to port 14. This passage remains open until the groove 8 passes exhaust port 14, and the piston cuts off further exhaust. A cushion then commences which tends to check the velocity attained by the piston, but not that of the valve carried thereby and traveling with equal velocity. Being free to move, the valve slides back until it meets stop 9.

In this position, the interior exhaust ports 7-7 are closed, and the admittance ports 5-5 are opened, and initial pressure air flows through the valve to the space in rear, driving piston out by reason of the excess area.

The valve remains in this back position, allowing air to flow through it until the piston has struck its blow, when the

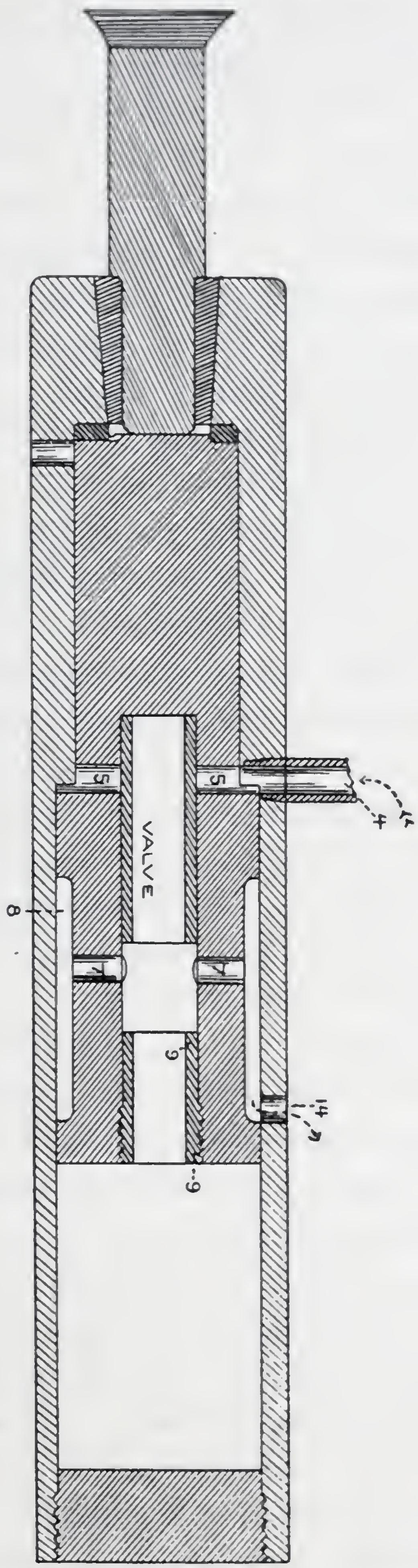


Fig. 4.

valve slides, by reason of its inertia, to its outer position, and the action repeats as described.

It will be noticed that full pressure is exerted until after the piston has struck, and also that the valve will shift at any point during the out stroke if the piston is stopped, provided that exhaust can occur. The possible limit of practicable variation of stroke is thus only limited by the distance found necessary to use for a rear cushion to prevent piston from ever striking the back cylinder head.

This varies from $\frac{1}{4}$ to $\frac{1}{3}$ of the stroke length, thus permitting a wonderful variability of stroke.

The tool, as described, worked very well at times, but it was discovered that the valve had a strong tendency to bounce back, especially on the front stroke. This unlooked for movement of the valve had very disastrous effects, as may be imagined, causing the action to be extremely erratic.

To obviate this trouble, brakes were applied to the valve, to prevent its sliding so easily. The machine ran well when it got a good start, but the valve was liable to stick at the wrong end of the chamber, and there was great difficulty in starting again until the piston had been jarred by hand so as to bring the valve where it should have been.

Other expedients, such as the use of rubber, lead, wood and other buffers, supposed to be inelastic, were tried in the endeavor to stop the bounce with but little success as anything soft enough to prevent bouncing was soon hammered out of all shape, the pieces clogging up the valve chamber.

All sorts of shifts, profoundly wise and exceedingly foolish, met the same fate, until we were almost disheartened and digusted with the perversity of things inanimate.

In pondering over the failure, the idea of counter-balancing the rebound of the valve by a smaller mass, colliding it with it at the instant rebound commenced, arose.

A little model consisting of a pipe, with two collars fastened to it, having between them another piece of pipe large

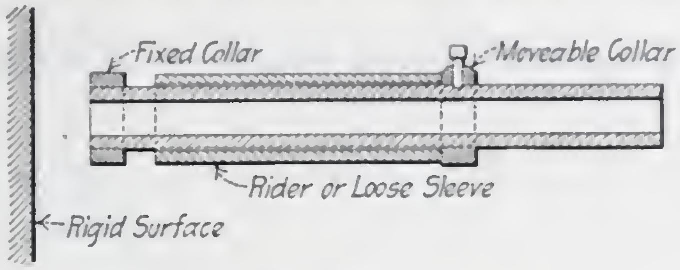


Fig. 5.

enough to slip freely on the outside of the other, and a little less in length than the distance between the collars, was made.

On holding this device about three or four feet above a block of steel; with the outer tube or "Rider" as it was named, bearing against the upper collar, it was dropped vertically. The lower end of the inner tube struck first and started to rebound, but the rider, traveling at the velocity due to the fall, slipped over the main tube, until it struck the lower collar, fast on inner tube, thereby checking the upward velocity of the rebounding inner tube, so that the combination practically did not rise perceptibly from the steel block, landing almost as dead as a chunk of putty.

It seemed as if this principle could be applied to the valve, so as to overcome its rebound, and at the same time give the freedom of motion necessary to good action.

A modification of the valve was made with a rider attachment, which, when tried, caused the tool to work with the regularity of clock work.

In designing the valve and rider, a study was made of the coefficients of rebound of various materials, and it was found that a great deal of difference in results and theory existed among the acknowledged authorities on applied mechanics, authors of distinction, such as Rankin, Welsbach and others, giving tables with wide variations for similar materials.

In order to be sure, recourse was had to experiment with different materials, to determine what proportionate weights the valve and rider should have to each other.

It has been demonstrated by mathematicians that the modulus of elasticity of rebound is equal to the ratio of the relative bodies after and before impact.

If a body, suspended from a small cord from a fixed point,

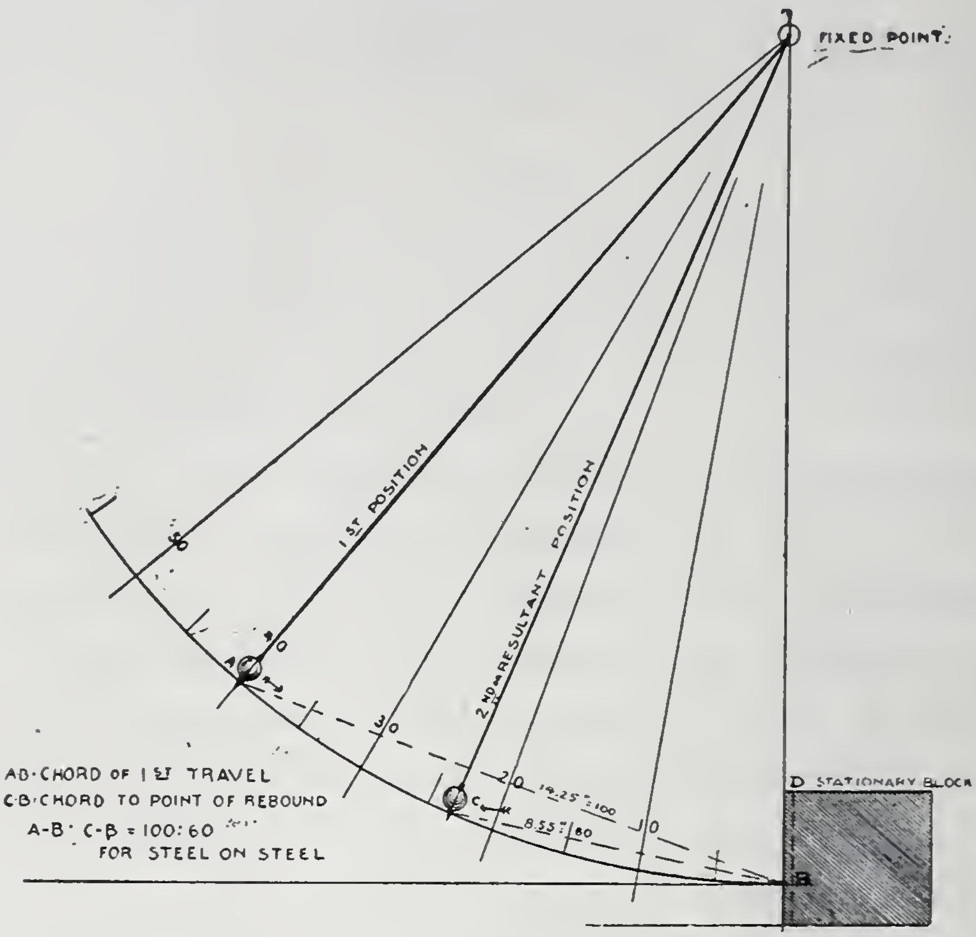


Fig. 6.

be made to oscillate like a pendulum, it will acquire a velocity at its lowest point, proportional to the chord of the arc through which it has swung, and if the arcs are not very long, the times of descent will be equal for different length arcs; hence, if the suspended body strike a stationary body when at its lowest point, and the angular distance through which it rebounds be noted, the ratio of the original to the return velocity can be determined.

It was found that for steel striking steel, it was as 100 to 60, and for steel striking vulcanized rubber, backed by steel, about 100 to 37. The fibre was used as it stands the pounding of the valve without itself disintegrating, or upsetting end of valve.

Knowing then the modulus of recoil, we can figure the velocity a body will acquire at the instant after collision on the rebound, if we know the velocity with which it struck.

If, in addition, we know the weight of the striking mass we can find the energy or momentum at that instant, and have only to make the weight of rider such that its momentum, due to the initial velocity, shall be equal to that of the valve rebounding, to practically eliminate the return movement of the valve. When two perfectly elastic bodies of equal weight meet, each rebounds with substantially the same velocity with which they met, but with imperfectly elastic bodies, of unequal masses and velocities; the rebound depends on which has the greater weight and velocity, and on the moduli of recoil, hence we can approximately calculate the weight of rider so that the valve will stop short, and any rebound will occur in the rider only. This rebound can be made so little that it does not influence he valve itself, and the desired result is attained.

In making these investigations, certain interesting points came up that are worthy of further study to fully understand the reasons for them.

The recoil certainly depends upon the elasticity of the colliding bodies, yet the ratios found by experiment, seem to bear no recognizable relation to the established coefficients of elasticity, given in text-books on the strength of materials. Evidently the amount of energy in the moving masses and the *area* of contact influence the result. If the striking area is small, the entire energy, converted into work, is exerted on a small unit of surface, causing a strain per unit area greater than the materials would stand. In this case the limit of elasticity, as ordinarily understood, might be exceeded when the work would be expended on tearing or crushing the material, instead of causing rebound.

On the other hand, if a body of equal weight and velocity to the one described, but having a much larger striking area, were to collide, it might easily be conceived that the strain per unit of striking area, would be less than the limit of elasticity of the materials, and that practically most of such energy would be consumed in bending or squeezing the materials,

which would spring back to their original position, and in so doing, force the colliding body back into space with a velocity dependent upon the strain produced and the coefficients of elasticity of the bodies.

To elucidate the truth of this hypothesis, would require a great deal of careful experiment and research, and would be suitable work for some mechanical laboratory connected with a technical school. Accurate information on the subject would be of great value. It might originate a new method of testing materials, although somewhat analogous to impact testing that is now in vogue, although the results in the latter system are derived from measurements of bends made transversely in the specimen struck. By this method, such results would probably be derived from a comparison with the velocities of rebound from standard substances, of bodies of given form and with given velocity.

The latest model of a direct acting chipping tool is shown in the accompanying sketch. You will note that the valve will move at any point of the stroke, if the velocity of piston be checked, and that within the limits for cushion described earlier in this paper, the stroke is variable.

While this variability of stroke is not so essential in a chipping hammer, or any tool of the second class of percussion where an interposed tool receives the blow, yet for machines of the first-class, such as rock drills, steam hammers, gold mine stamps, &c., such variability is desirable and essential to attain the best results.

In this hammer the exhaust takes place at very nearly the initial pressure, hence a great deal of energy contained in the compressed air is wasted, although the piston velocity on the down stroke is great, giving a powerful blow.

It seemed as if some of this waste might be obviated by working the air compound, using a different form of inertia valve so as to retain the good features of the device.

It was evident that a constant supply of initial pressure

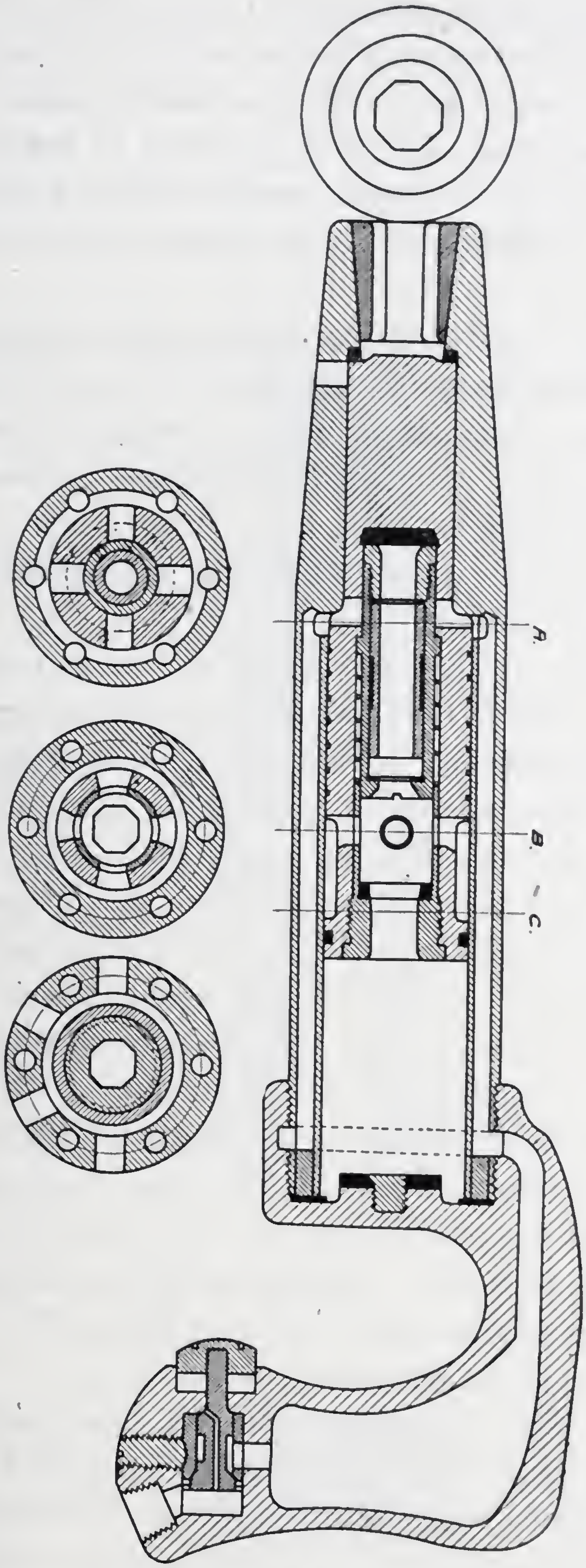


Fig. 7.

air should be furnished, available at any point of the stroke, but that it should have access to one end of the piston at certain specified times only, and that the valve should permit of opening a passage from this side of piston to the other, which necessarily should be of larger area to allow of the locked in charge of high pressure air acting expansively on both piston areas.

It was also a condition that during the movement of the piston under initial pressure, that the other end of the cylinder should be open to exhaust in such a way that variability of stroke would result, and sufficient cushion formed to prevent piston striking cylinder head.

These conditions were fulfilled in a machine of the type shown in the illustration.

An annular groove was provided on a portion of the exterior of the piston that was in register at all points of the stroke with an admission port of high pressure air. An axial valve chamber was provided, open at the rear end in the body of the piston, having from it ports leading to the constant supply of motive fluid ; other ports leading to a point adjacent to the small diameter of the piston and exhaust ports, arranged so that exhaustion could occur through them during the majority of the back stroke, but be closed by the motion of the piston for the remainder of the stroke.

A tubular valve was placed in this central chamber, having on its exterior surface an annular groove, so placed that when the valve was at the outer end of its travel, it would register with the ports from the constant source of supply, and the ports leading to smaller piston area, while at the same time a port through it would permit of exhaustion.

In action, the pressure against the small area of piston drives it back, air in the rear meanwhile having a free vent through the exhaust ports until the piston, in its travel, cuts off exterior exhaust port, thus cushioning the air remaining back of the piston and checking velocity of the piston when the valve moves by its inertia to the rear end of its travel.

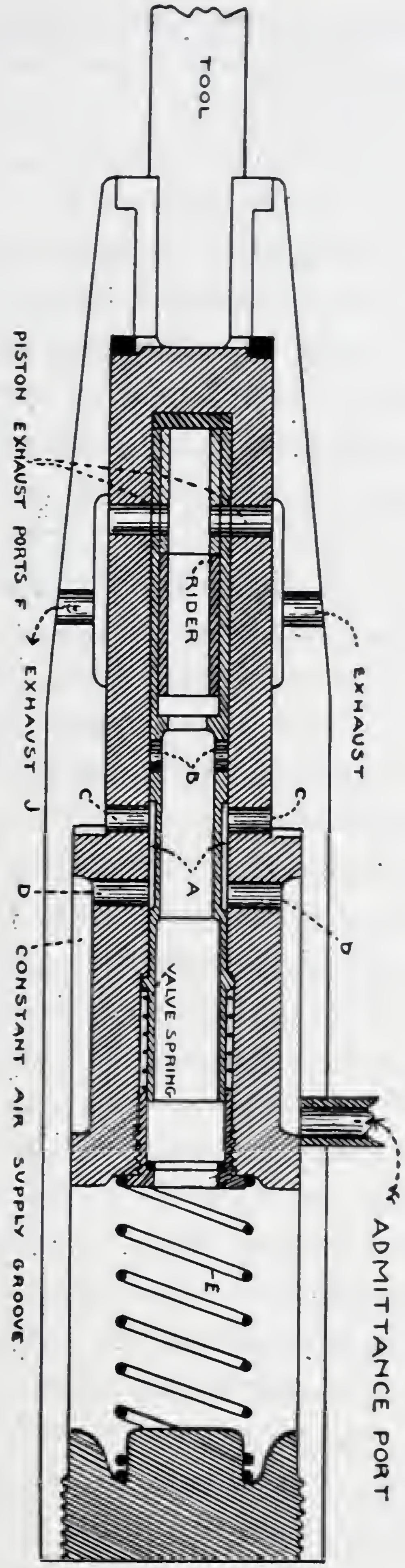

TOOL
PISTON EXHAUST PORTS F
RIDER
EXHAUST J
EXHAUST
B
C
C
A
D
D
CONSTANT AIR SUPPLY GROOVE
VALVE SPRING
E
ADMITTANCE PORT

Fig. 8

In this back position the supply of high pressure air is cut off, as is also the exhaust port, and a port in the valve itself, registers with the port leading to the small piston area, permitting the air locked in in front of the piston, free passage to the rear. The pressure immediately tends to equalize on both ends of piston, and owing to the larger area in the rear, the piston is forced out under the force of the expanding air from the front end of cylinder, continually decreasing in pressure as the piston moves, and the volume or space increases. The piston striking causes the valve to shift back to its original position, and the action continues.

It is obvious that if the piston were back when at rest that there would be no locked-up air to expand, so that it could not start, and to overcome this difficulty, a spring is placed back of the piston just strong enough to force it out when no air is admitted. No loss of power results, as the energy stored up in it on the back stroke is given out on the front stroke, and it serves to help cushion.

The valve also is provided with a light spring sufficient to keep it in the outer end of its travel when the piston is at rest, so that all will be in readiness to start on opening throttle valve. The inertia of the valve on the down stroke is sufficient when the piston is constantly accelerating in velocity, to prevent this spring closing the valve prematurely.

The proportion of expansion can be determined if the clearances are known, for any ratio of piston area. It has been found that for air the proportion of 10 to 3 is good, as this gives a terminal exhaust pressure of about 2 pounds per square inch if 80 lbs were the initial pressure. This permits of prompt exhaustion, and no vacum is formed in the rear, as would be the case if greater ratio of expansion were adopted. Such a ratio could be used with steam, as a condenser might be attached, but no experiments have been made in that line.

With this tool, about three times as much work can be done with the same volume of air, as with a direct acting tool,

exhausting at initial pressure, or the same work can be done with $\frac{1}{3}$ of the volume of air. It may be seen that the diameters of the tool might have to be larger to effect these results, and that the mass of piston would be larger in consequence. In practice, a longer stroke has been adopted in order to avoid the back kick, due to large diameters, as explained earlier. The length of stroke does not affect the ratio of expansion, as the volumes in front and rear of piston change in definite proportion.

The velocities attained in forward and back strokes in either the compound or single acting hammers, can be calculated with fair accuracy, when the diameters, piston areas, pressure per square inch, length of stroke and weight of piston are known, as these are constants or known variables. The amount of friction, leakage and loss due to overcoming inertia, are difficult to determine exactly.

Knowing the velocities and the volumes of motive fluid used, the number of strokes per minute and the amount of air consumption, can be closely approximated, and in practice count of the number of strokes and accurate measurement of air consumption by meter, check out within from five to ten per cent. of the theoretical results figured.

Thus a tool can be intelligently designed to do the work expected of it, as regards force of blow, frequency of stroke, and air consumption at any given pressure.

This valve motion would seem to be applicable to a great variety of purposes, even to running a compound engine with tolerable economy. The power of the stroke due to expansion is not 5 per cent. less than that due to initial pressure, on the small area, and a machine can be designed to strike by either initial pressure or expansive pressure, as desired. The latter has been chosen as giving simpler construction in the tool.

The valve motion described, and the anti-bouncer arrangement, are covered by several patents, as is the poppet valve tool described.

The tools, as now made, run very satisfactorily on long and severe tests, and are practicable and useful.

Endurence tests of materials and detail parts are now being made with the view of discovering all weak points.

When these have resulted satisfactorily, the tools will be put on the market.

Owing to the great number of strokes and the small cylinder volumes in the tools already experimented with, it has been impossible to make indicator tests, so a study of the action of tools was only possible by observation of action, air consumption and number of strokes per minute, as the valve itself could not be seen at work. It followed, that by induction only, could one arrive at the causes of some of the erratic performances and failures of the tools.

May 11th, 1900.

NOTE.—The Engineers' Society is indebted to the "Engineering News" and the "Iron Trade Review" for cuts illustrating this paper.

DISCUSSION.

MR. SCOTT—The paper is one of the most interesting and profitable that the Society has heard. It is the story through failure and trial to success, and those of us who have had anything to do with experimental work have enjoyed a story of this kind very much. It is a story of the different points that have been encountered, and in which one point after another has been overcome and made useful. This is particularly interesting to the Society.

MR. GOW—Mr. Albree, how many cubic feet of air is necessary for operation of an ordinary hammer?

MR. ALBREE—I would say, as I said a few moments ago, it depends upon the stroke of the hammer. It is a little indefinite; but you can safely say that it will run from 15 to 25 cubic feet per minute.

Mr. Gow—I put the question to an agent of a tool on the market and he said it would run about 75 to 80 cubic feet per minute.

Mr. Albree—One thing I meant to say, and that is in regard to the crystalization of the parts under constant hammering. I have tried almost every kind of steel known but have not yet found a material of the kind for those valves that won't break up inside of two or three days. We have had recourse to valves made of other materials, which have given very great success. I do not care to say just at the present time what this material is. I would like also to make acknowledgment to the Pittsburg Supply Co. for the loan of the two big air tanks.

Mr. Hirsch—I think this Society is very much indebted to Mr. Albree for this very interesting paper.

It was voted that the thanks of the Society be tendered Mr. Albree for his excellent lecture.

It was also voted that the chairman of the Programme Committee (Mr. Albree) get up a paper, whenever he had any difficulty in finding anybody else to do it.

On motion the Society adjourned at 10:20 P. M.

Reginald A. Fessenden,
Secretary.

MEETING OF THE CHEMICAL SECTION.

Pittsburg, Pa., May 17, 1900.

Regular meeting of the Section held in the east lecture room at the Carnegie Library. Fifteen members were present.

It was decided by mutual consent to continue the assembling at a convenient place for dinner before the meeting.

The meeting then adjourned to the reference room where the members spent the evening in examining the excellent technological library.

G. O. Loeffler,
Secretary.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two-hundred and sixth regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture Room of the Society's House, 410 Penn Avenue, Pittsburg, Pa., Tuesday evening, June 19, 1906, thirty-nine members and visitors being present. The meeting was called to order at 8:30 o'clock, the Vice-President, Mr. H. W. Fisher, being in the chair.

The minutes of the previous meeting were read and approved.

For the Board of Directors, the following applicants were reported as passed and to be voted for at the next regular meeting.

MR. SUMNER B. ELY, - - Assistant Superintendent,
McKees Rocks Plant of Pressed Steel Car Company.

MR. HOMER EDWIN WHITMORE, General Engineer,
With E. K. Morse, 511 Larimer Avenue, Pittsburg.

The following gentlemen were balloted for and duly elected to membership:

HARRISON W. CRAVER, - Reference Assistant in Technical Science,
Carnegie Library, Pittsburg, Pa.

ROBERT C. FALCONER, - Assistant Engineer,
With Pennsylvania Co., care Pennsylvania Co. Penn Avenue, Pittsburg.

ARTHUR B. JONES, - - Manager,
Versailles Works, The Baker & Adamson Chemical Co., Versailles, Pa.

KRISTIAN A. JUTHE, - - Superintendent,
Pittsburg Screw & Bolt Colt Co., Pittsburg, Pa., 326 Princeton Place, E. E., Pittsburg, Pa.

HEW C. TORRENCE, - - Manager,
Pittsburg Office, The Brown Hoisting and Conveying Machine Company, Cleveland, Ohio. 1112 Carnegie Building, Pittsburg, Pa.

None of the committees had any reports to make.

MR. SCHELLENBERG: Gentlemen, our attention has been called to the new photograph of our Ex-President, Mr. William Metcalf, who is probably one of our oldest members. I move that we acknowledge its receipt with our thanks as a token of the appreciation of the society. Motion Carried.

Mr. Albree presented the following letter from the Engineers' Society of Western New York.

To the Secretary of the
Engineers' Society of Western Pennsylvania,
R. A. Fessenden, Esq.,
410 Penn Avenue, Pittsburg, Pa.

DEAR SIR:—

The Pan-American Exposition to be held in this city from May 1st to November 1st, 1901, will be carried out in a manner and on lines unequaled by any previous Exposition held in this Country, excepting the World's Fair of 1893, and in some respects will distance even the latter.

As will be seen by the literature sent you herewith it is intended to house the exhibits in buildings presenting a beautiful outline and setting, and by the individual States and by the Republics and Colonies of this Hemisphere there is no question that the educational results which will follow the Exposition will be great.

In view of the foregoing the Engineers' Society of Western New York have considered it opportune to call the attention of Engineering Societies throughout the Continent to

this Exposition, as presenting a most favorable opportunity to gather together an engineering exhibit and for holding either a joint congress, or, that each Society might hold its annual Convention during the Exposition.

The above Society appointed the undersigned a committee to consider the question of such an exhibit and Convention or Conventions as suggested and to present a plan therefor to the Society, on June 4th, 1900.

To assist us in formulating such a plan we would be pleased to receive suggestions from you, or, if possible, from a Committee of your Society, as to the probability of our being able as joint Societies to install such an exhibit and if you would favor, either a joint Convention, or, separate Conventions of Engineering Societies at this city during 1901.

We believe that with such an exhibit of models, drawings, plans, etc., of engineering works, as could be collected in this Country and South America, and with Convention during the Exposition, most beneficial results could be secured by all participating therein. By replying to the above before June 4th, you will confer a great favor on the undersigned.

THOMAS W. SYMONS, M. Am. S. C. E., Major U. S. Engineers. E. C. LUFKIN, M. Am. S. C. E., M. Am. S. M. E. EDWARD B. GUTHRIE, M. Am. S. C. E., M. Am. S. M. E.	Committee of the Engineers' Society of Western New York.

MR. ALBREE—While we may not all be able to go there it would add a great deal to the pleasure of those who do, as there will be steps taken to entertain the visiting engineers. It seems to me it would be well for us to offer our co-operation and assistance. I would propose the following :

Resolved: that it is the sentiment of the Engineers' Society of Western Pennsylvania that a union meeting of the various Engineering Societies of this and other lands, to be held in Buffalo some time during the Pan-American Exposition, for discussion of engineering topics, combined with drawings and other objects connected with the profession, would be desirable; and that this Engineers' Society will heartily cooperate with the Engineers' Society of Western New York in forwarding the success of the project.

Mr. Johnson—What time is that meeting to be?

Mr. Fisher—The time is not specified. It is to be some time during the Exposition which is from May 1st to November 1st.

Mr. Albree—As I understand the matter no definite plans have been formulated, but they want to know if we will co-operate with them. It could be taken up and a committee appointed to consult with them.

Mr. Fisher—I think this movement is a commendable one, and it is always attended with much good to have meetings of this kind during an Exposition. I think it ought to be heartily endorsed.

Mr. Scott—I am not quite clear as to what the word cooperate means in the resolution. Does that mean financial co-operation in the general arrangement, or does it mean that we shall help to furnish the exhibits, models, drawings, etc? It might be made to apply that we were to make such appropriations. It seems to me that it is a little more than we are at this time ready to commit ourselves to. We are in general sympathy with the movement, but their plans are not definitely laid out, and it seems to me that it would be well for us to communicate with them as a society or through a committee which we could appoint, stating our general accord with the plan and asking them in what way we can co-operate and help them. Get their suggestions and then we can reply as we see fit. Probably Mr. Albree has such an idea in making the motion.

Mr. Albree—I will amend that motion and will move that the president appoint a committee of three to take up the matter with the Engineers' Society of Western New York.

A Member—The committee should be given considerable power to go ahead and formulate plans, as our next regular meeting does not occur until next September, and I suppose a great deal will have to be done before that time. I think the committee should be empowered to act for the society.

Mr. Enstrom—I do not see the object of the motion. I do not see the necessity of a special committee. I think Mr. Albree should allow the matter to be laid before the Board to take such action as they think necessary.

Mr. Johnson—Before you put that motion I would suggest that the Board will not hold any meeting until September, unless they are called specially to attend to this matter.

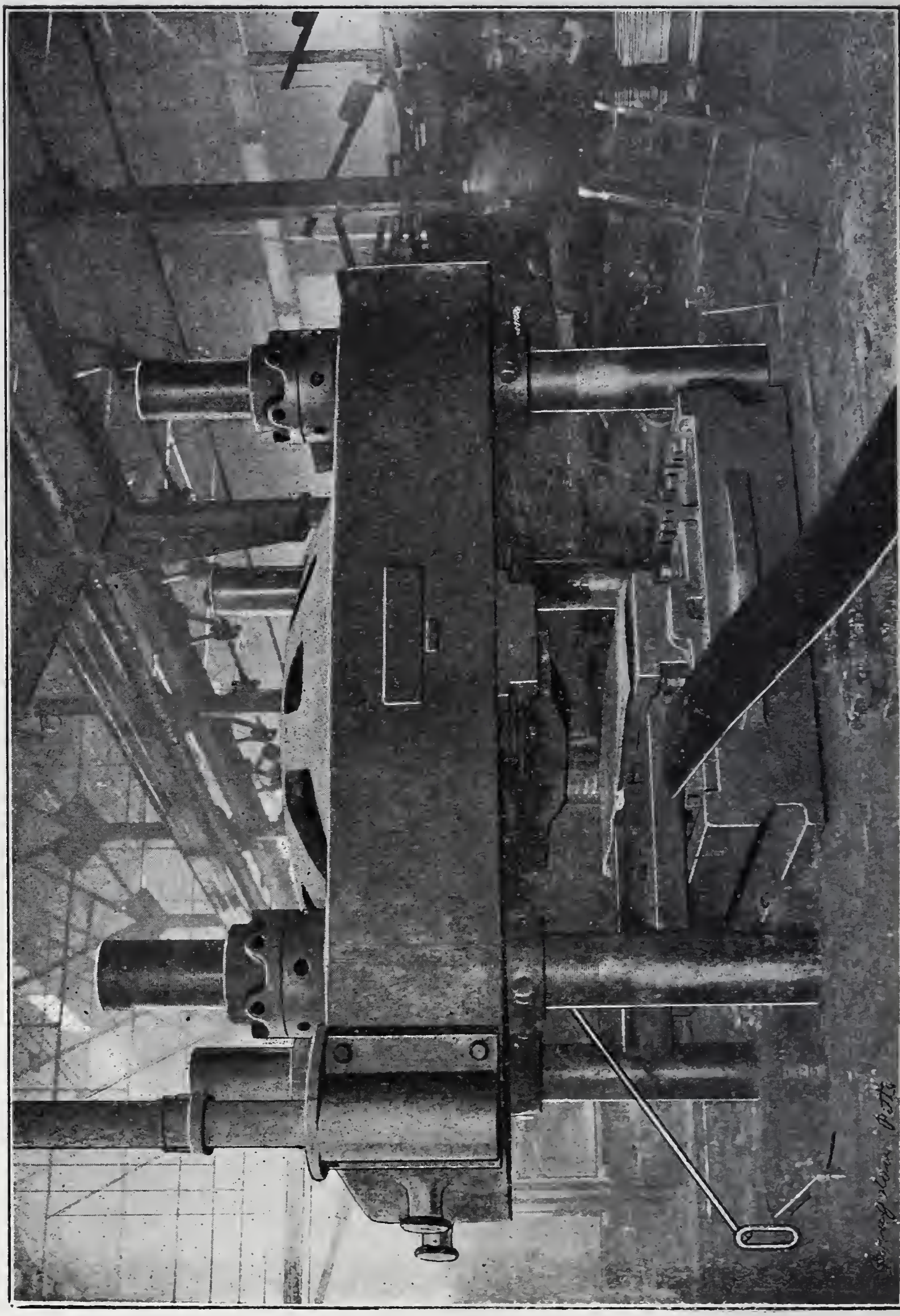
Mr. Fisher—I might say that this matter was brought up at the Board meeting. It was of such importance that the Board thought it should be brought before the society take action on it.

Mr. Albree's motion as amended was stated. Moved that the president appoint a committee of three to take up the matter with the Engineers' Society of Western New York. Motion Carried.

The president appointed the following members to act on this committee.

Messrs : C. B. Albree, H. W. Fisher, C. W. Ridinger.

Next in order was the paper of the evening by Mr. Sumner B. Ely, entitled, "The Pressed Steel Car, With Some Experiences in Erecting Them in Egypt."



THE PRESSED STEEL CAR, WITH SOME EXPERIENCES IN ERECTING THEM IN EGYPT.

BY SUMNER B. ELY.

Pressed Steel, as we know it to-day, being quite a modern invention, it may be of interest to hear of some of the details of its manufacture. I propose to talk on the processes and means of handling pressed steel, in the construction of an all steel railway car, particularly as done by the Pressed Steel Car Company of this city.

I have said that pressed steel was a modern invention; however the idea of shaping steel by means of dies is probably very old, but the idea of pressing large plates into irregular shapes of all descriptions is quite new.

We are all familiar with the corrugated boiler flue; and these little models illustrate well its advantage over the straight flue. This first model is a miniature boiler flue, made of very thin material and is quite flexible to the pressure of one's fingers. The other is a model of the corrugated flue, made exactly of the same amount and thickness of material as the first; and in all respects like it except for the corrugation. The immense stiffness of the latter is astonishing. The corrugated flues are manufactured by the Fox Pressed Steel Company of Leeds, England, who also manufacture pressed steel cars of various descriptions, including a pressed steel truck. An American Fox Pressed Steel Company was started, using the English designs, but manufacturing the trucks only, and

not the car bodies. At this time the Schoen Pressed Steel Company was manufacturing a pressed steel truck, and many specialties of pressed steel; and rapidly developed an American steel car. To one at all familiar with the difference between American and English railway practice, the difference in design of the Fox and the Schoen steel car is not astonishing. Most of the cars built by the Fox Company, however, are for use in India, where, on account of the white ant, I am told it is impracticable to use wood.

The Fox Pressed Steel Company of America and the Schoen Pressed Steel Company are now consolidated into the Pressed Steel Car Company.

There have been within the last fifty years a few attempts to build steel cars, but so far as I am aware, excepting the Schoen and Fox Companies, these cars have been built like a bridge—i. e., of rolled sections and plates. These were not a success, probably due to both theoretical and financial reasons.

This brings us to the theory of pressed steel and its advantage over a built up structure. Expressed concisely, pressed steel gives us maximum strength for minimum weight. As an example take a channel say 30 feet long, which is used as a side sill of a car. Suppose that for purposes of strength we require the web to be $\frac{1}{4}$ inch thick and 17 inches deep at the point of greatest stress. If the channel is rolled it must be 17 inches deep its whole length, whereas one that is pressed may be 17 inches at its centre and taper to say 10 inches at its ends, as shown in figure 1.

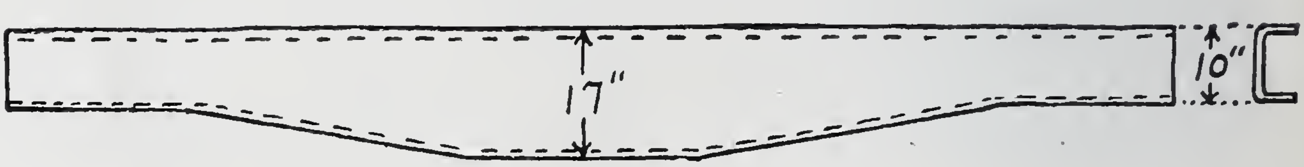


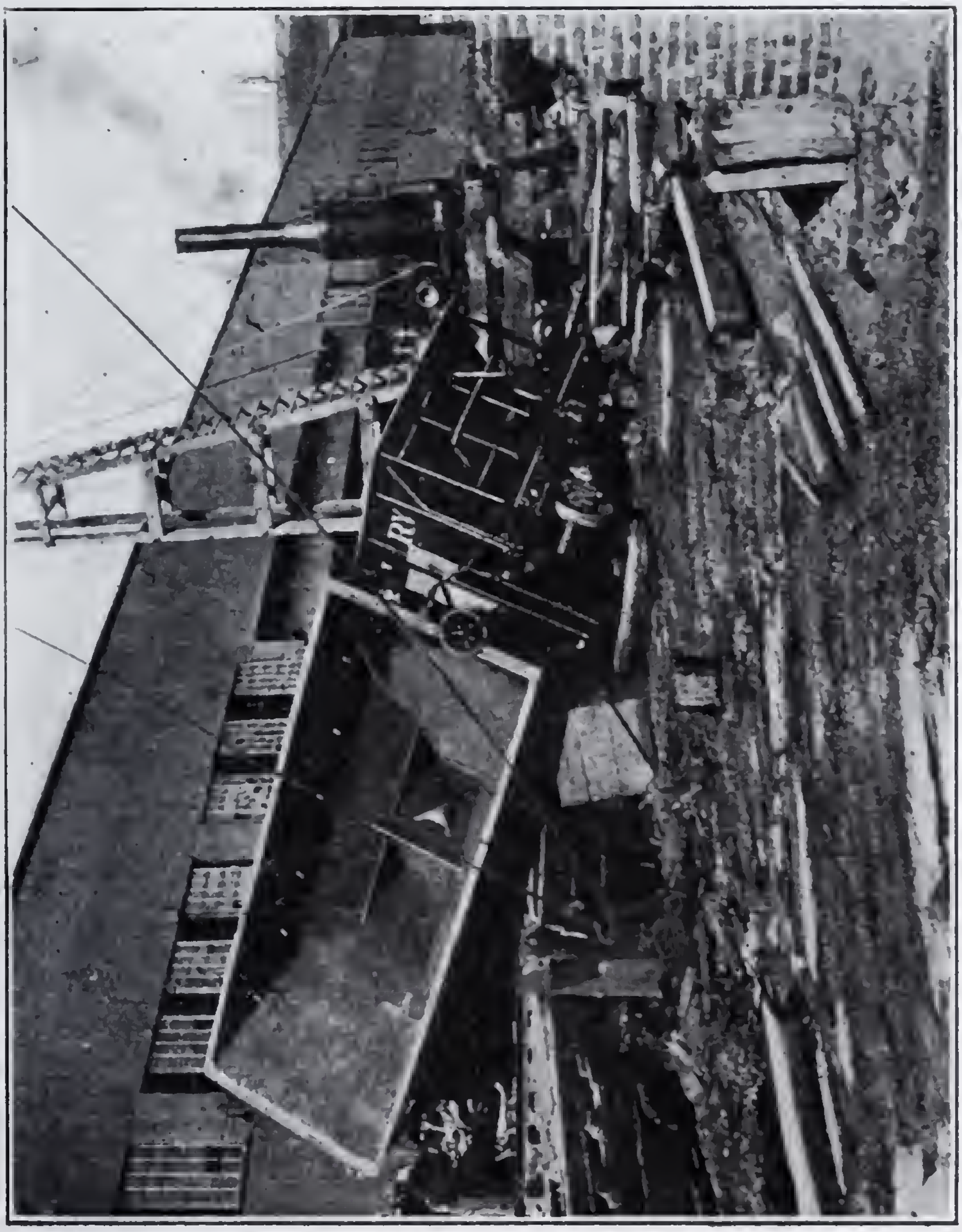
Fig. 1.

50 Ton Ore Car.

Thus we have the same strength as given by the rolled section of uniform depth, and about one-third less weight. This principle of being able to place the metal where needed, applies to all pressed steel work; and as before stated gives the necessary strength with the minimum amount of material.

Another immense advantage of a pressed steel car over one built of rolled shapes is the great reduction in the number of rivets. The pressed car is made of a few very large pieces pressed into the proper shape with necessary flanges, while the rolled car is made up of many small pieces and connecting angles; hence the very greatly increased number of rivets.

Let us look at what figures we obtain in the case of a pressed steel ore car such as used by the Great Northern Railroad (marked L. S. & I.). This car is of the double-hopper bottom type as shown in the photograph, and will carry 100,000 pounds of ore. The photograph of the wrecked car is introduced as it shows the shape of the car inside. The light weight of the car is 28,800 pounds, giving, with the load, a weight on the rails of 128,800 pounds. Now, dividing the total weight on the rails by the light weight, we obtain about 23 per cent., which represents the dead weight that must be hauled, while 77 per cent of the total weight hauled is the paying load. Let us look at a wooden car as a comparison—the best of them will hardly show 35 per cent. dead weight. Granting a case of 33 per cent. we then find with the 23 per cent. of the steel car, a gain of 10 per cent. This means, not only with the same number of locomotives can 10 per cent. more paying load be hauled, but it means, remembering that the ordinary wooden car has a capacity of 60,000 pounds, many less cars on the road; with that same reduction in journals, moving parts and train lengths; the advantage of which it is unnecessary for me to mention. A steel car always seems to me somewhat like a steel ship. If we had a vessel built of wood with the tonnage that the St. Louis has, it would have a greater displacement, or what is the same thing, weight, than has the St. Louis. Certain



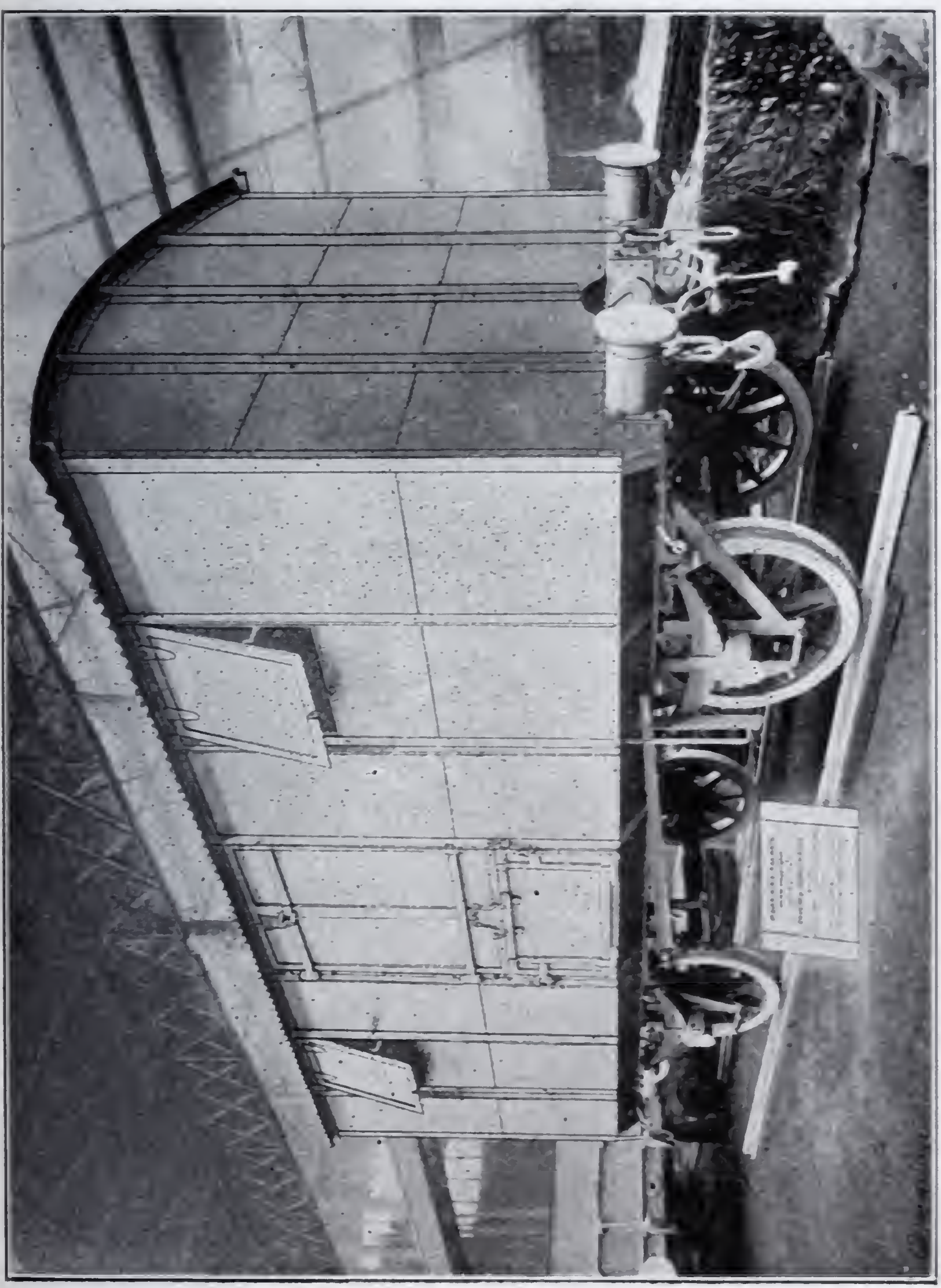
50 Ton Ore Car.

it is that a car capable of carrying a heavy load is lighter when built of steel than of wood. This somewhat explains why a steel car has a less first cost per carrying ton, than has a wooden one. So that not only does the steel car show a superiority in saving from dead weight, but also in first cost, outside of any gain due to longer life, saving in cost of repairs, etc.

I might here add that one of the first questions brought up is that of rust. This is a large subject which would take a paper by itself. Suffice it to say that so far experience has shown no trouble. The ordinary steel hopper bottom car has an inside bright like a shovel and the outside should be painted at least once a year.

You are probably all familiar with the manufacture of steel cars to a greater or less extent. The steel, after coming from the steel yard, goes into the shearing department, then to the pressing department, then to the punching department, and then into what is called the construction department. In this department the floors, ends and sides of the cars are assembled and riveted together, all the machine rivets being driven here. Then these parts go into the erection shop, where they are fitted together to form the car and finally hand riveted.

In the shearing department are shears of various sizes, kinds and capacities. However, most of the work is that of shearing plates, which seldom run thicker than $\frac{3}{4}$ of an inch. The special feature of this department is the various odd shapes that have to be cut; and many problems arise of laying out on a flat surface the shape of a complicated pressed piece. This will require some modification of the ordinary way of developing solids as given in text-books on descriptive geometry, due to the stretching of the piece; especially when the piece is to be pressed hot. These shapes involve many special shear knives, made with proper curves and offsets, as many of the cuts are impossible on the ordinary shear. Some pieces after pressing are trimmed by the shears; but a very great number are of such shapes that it is impossible to do this after

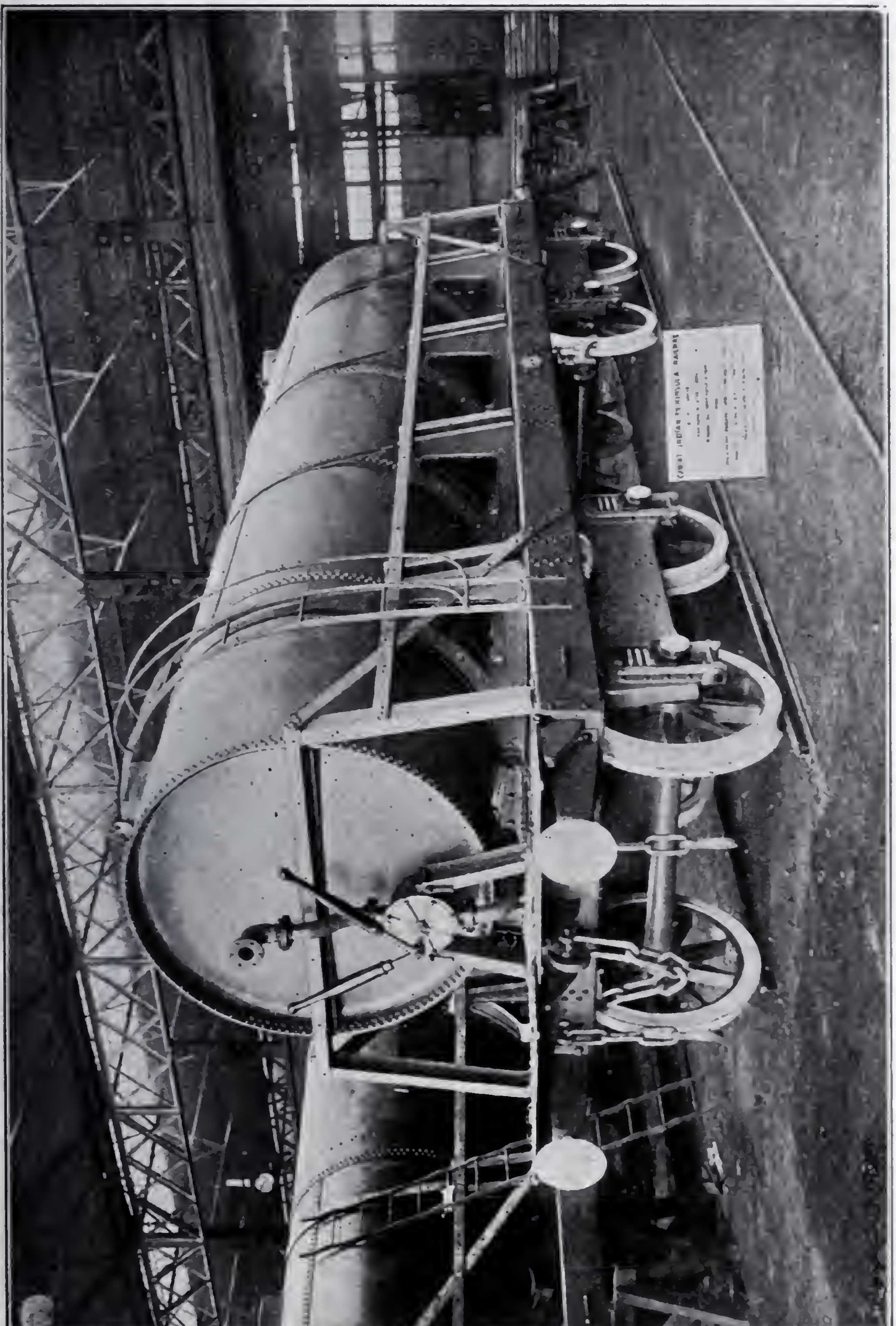


Built in England for India.

once being pressed. Hence you can see the importance of getting the flat blank correct to start with. In the Fox Pressed Steel Company, in England, I noticed that they had several special machines and heads for shearing pressed shapes that the ordinary plate or angle shears would not catch. This, however, is an unnecessary operation, even from a standpoint of looks, as these pieces so trimmed were not seen when in position on the car; and illustrates the fact that the English devote more time to the finish of machinery than we here in America think necessary.

In the pressing department, which is perhaps the special feature of the business, there are presses of all sizes and capacities, from 30 or 40 tons up to 800 tons. You are all familiar with the action of these presses, which are worked entirely by hydraulic pressure. Most are built by Bement, Miles & Company, and consist essentially of four upright columns set in a heavy iron foundation, at the top of which in a horizontal position is the top plate of the press; and against this comes a moveable bottom plate, the piece to be pressed lying between the two. Very important factors in pressing are the dies or forms between which the piece is shaped. These dies are always made in two portions, the upper half being bolted to the top plate of the press and the lower half to the bottom. Naturally, from the work done these dies vary in size from the small ones of a few inches to ones that measure 10 or 15 feet; most of them are made of cast iron, and many have hard steel wearing strips that can easily be replaced when worn by the rubbing of the pressed pieces. It is hard to say what the best metal for a die would be, but I suppose some alloy will some day be found that may combine the necessary properties.

Some of the work done on these presses is done with the piece cold. Other shapes are such that it is impossible not to tear the piece unless it has been heated to a red heat. Some shapes are such that two, three or more pressings by different



Built in England, showing Fox Truck.

dies are necessary ; each operation bringing the piece a stage nearer the shape desired. In hot work the dies, will of course, expand and contract with heat ; a die 8 feet long will expand somethimg like $\frac{7}{8}$ of an inch, and it is of course necessary that the dies be at the proper temperature, independently of what may be the temperature of the piece ; so that here comes in a little complication and this point must be watched closely in order to obtain satisfactory results.

Another point in this connection which I alluded to when speaking of shearing blanks, is the stretch of the pressed piece. The best way to make this clear will be to take an example of a piece of the following shape as in figure 2.

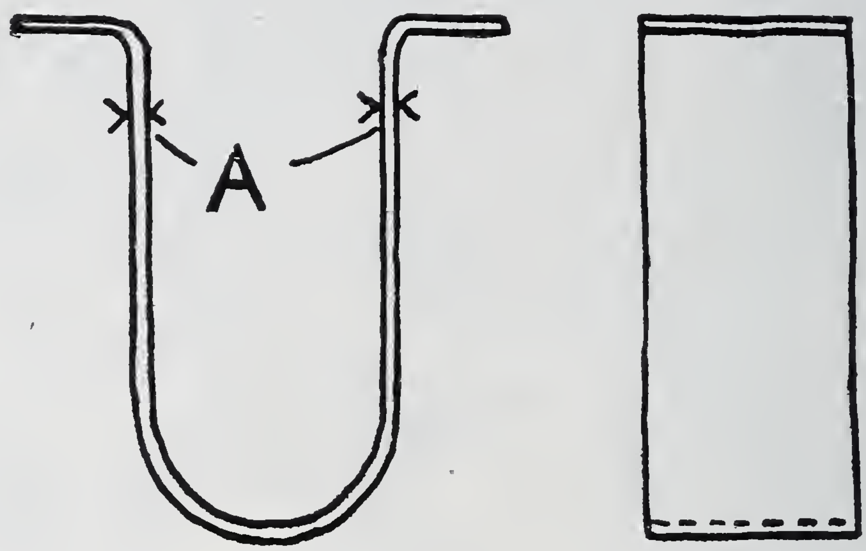


Fig. 2.

The steel used in this piece is $\frac{3}{4}$ inch thick with a width of 6 inches. At the point shown by the dimensions "A" the thickness will be diminished about $\frac{1}{16}$ inch ; and as you caliper down from this point the thickness gradually increases to $\frac{3}{4}$ inch. The top flanges will show no appreciable stretch. The total length of the steel—about 60 inches—will stretch about 4 inches ; so that the piece will be cut 4 inches shorter than the figured length would indicate.

The sketch, figure 3, shows the outlines of the top and bottom dies ; the top die has an increase in width of $\frac{1}{8}$ inch at

A over that at B otherwise there would be a hump at these points on the inside of the pressed piece. The lower dies' sides are of course straight.

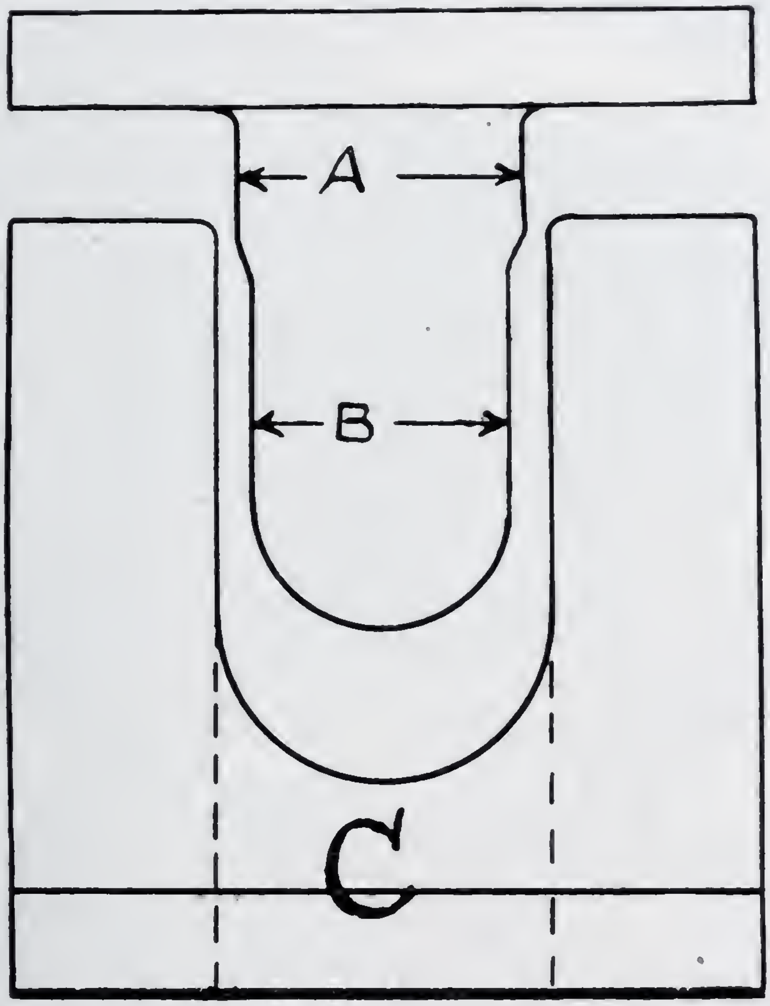
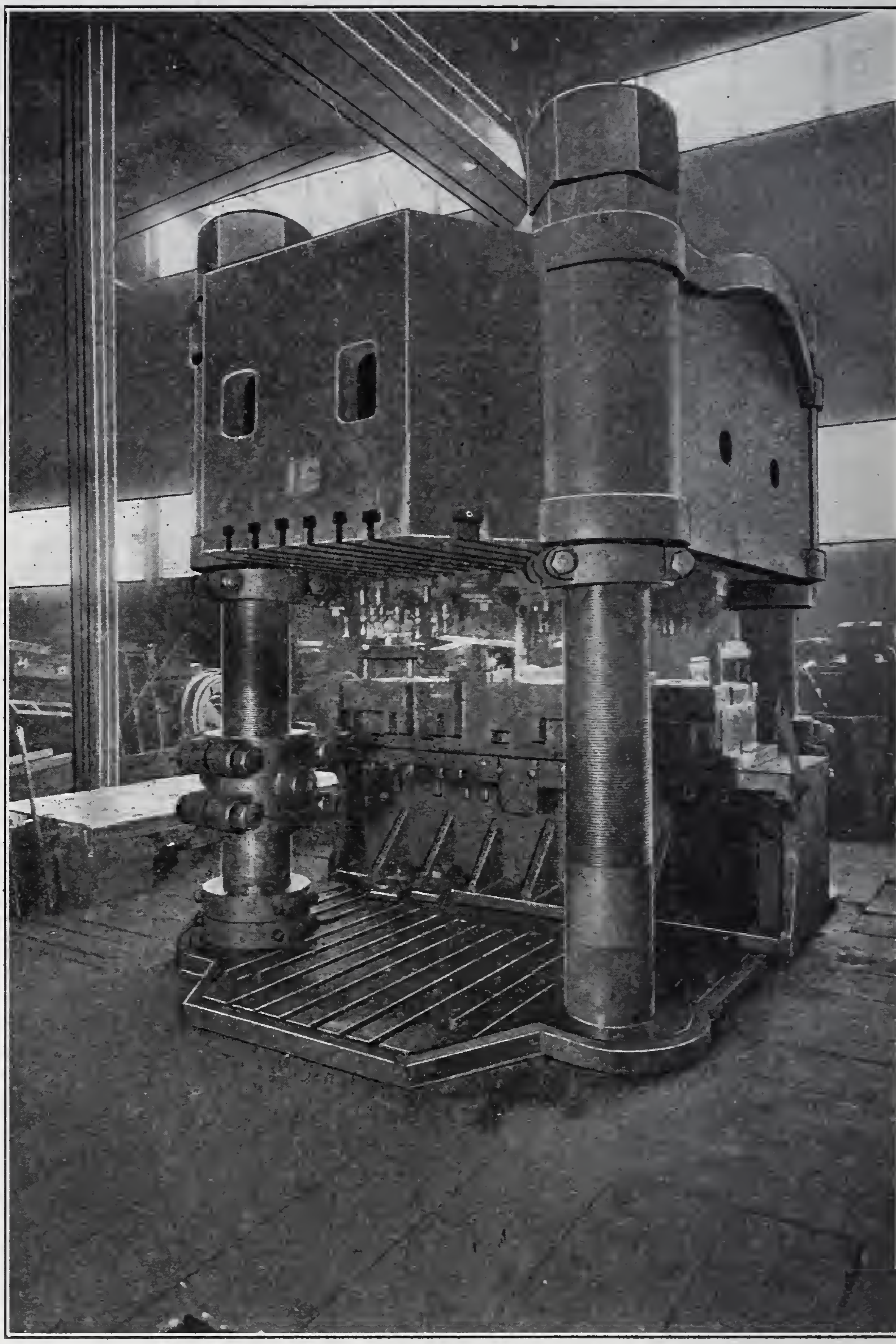


Fig. 3.

There is often trouble with the pressed pieces sticking to the dies and giving a distorted piece after it is pried out with pinch bars. On all large presses a false bottom is employed to overcome this. This is a movable piece for the bottom of the lower half of the die ; and in the above figure the dotted lines shown on the lower die would represent the sliding surfaces ; the whole portion C raising and thus pushing out the piece. This is actuated by a small piston inside the large piston of the press. Thick oil is also a help and has the advantage of saving the wear on the die ; and also in hot work it burns on the piece helping to keep the proper temperature



Press and Gang Punch.

while the piece is being adjusted to the gauges. Sometimes dies are constructed as shown in figure 4, still using the same

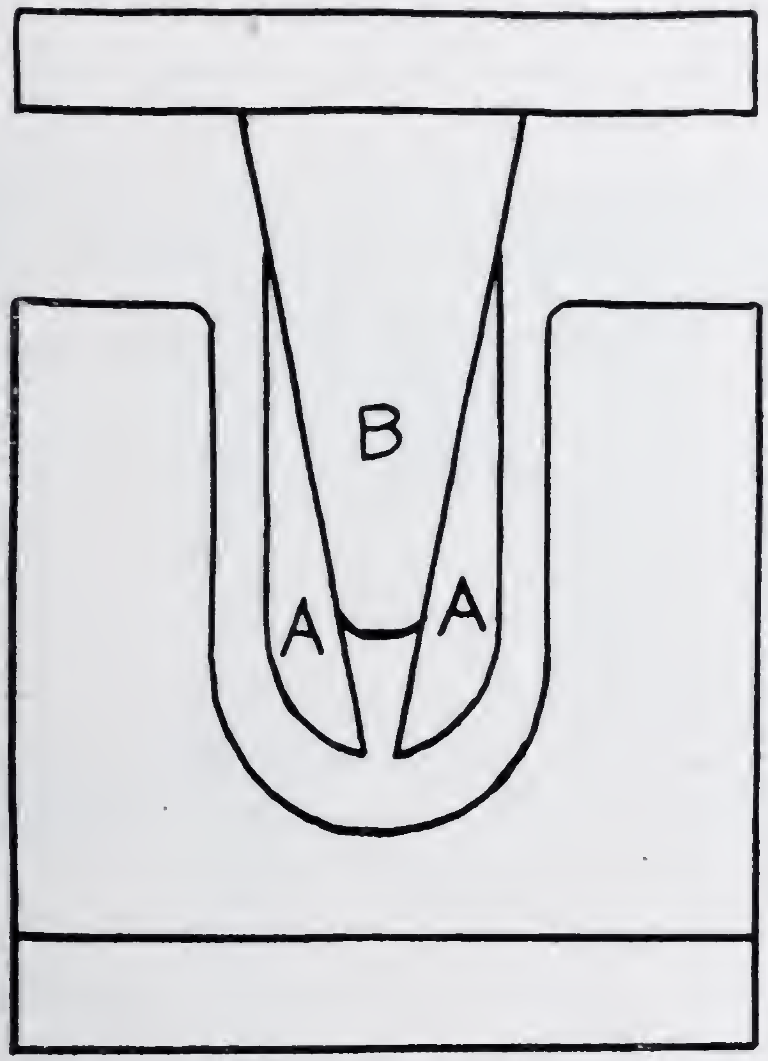


Fig. 4.

shape already shown as an example. The upper portion of the die being made in three pieces, the portions A sliding on B, the wedges thus release as soon as the press is lowered.

Presses are also much utilized for gang punching, shearing and slotting. In these operations the same methods are pursued, the dies being constructed to hold punches or shear knives. Many odd shaped blanks are cut out complete at one stroke: it would be hard to say what maximum number of holes could be punched at one stroke; but if the punches are made in different lengths, it allows an even distribution of pressure throughout the stroke. Thus by proper adjustment

of this lead of one punch over another, according to the number of punches used, the maximum capacity of the press can be reached. The same may be said of the shearing, the proper angles being given to the knives.

If an ordinary steam engine indicator with the proper reducing valve be attached to the cylinder of the press, and a rig attached to the movable press plate, the following card diagram will show the general results obtained when a single straight flange is turned up on a plate.

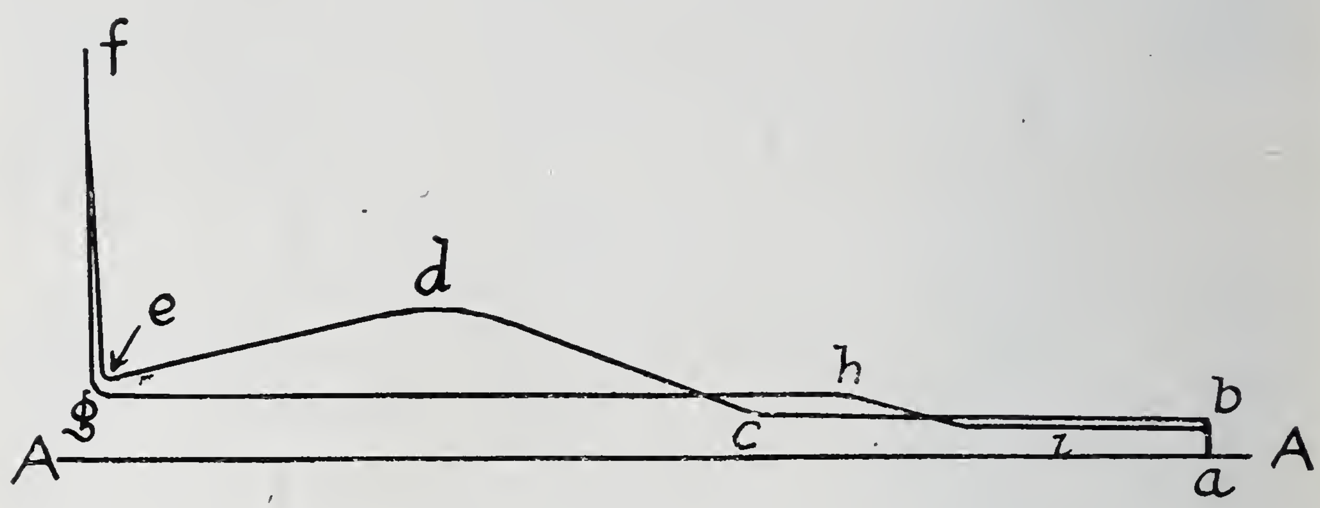
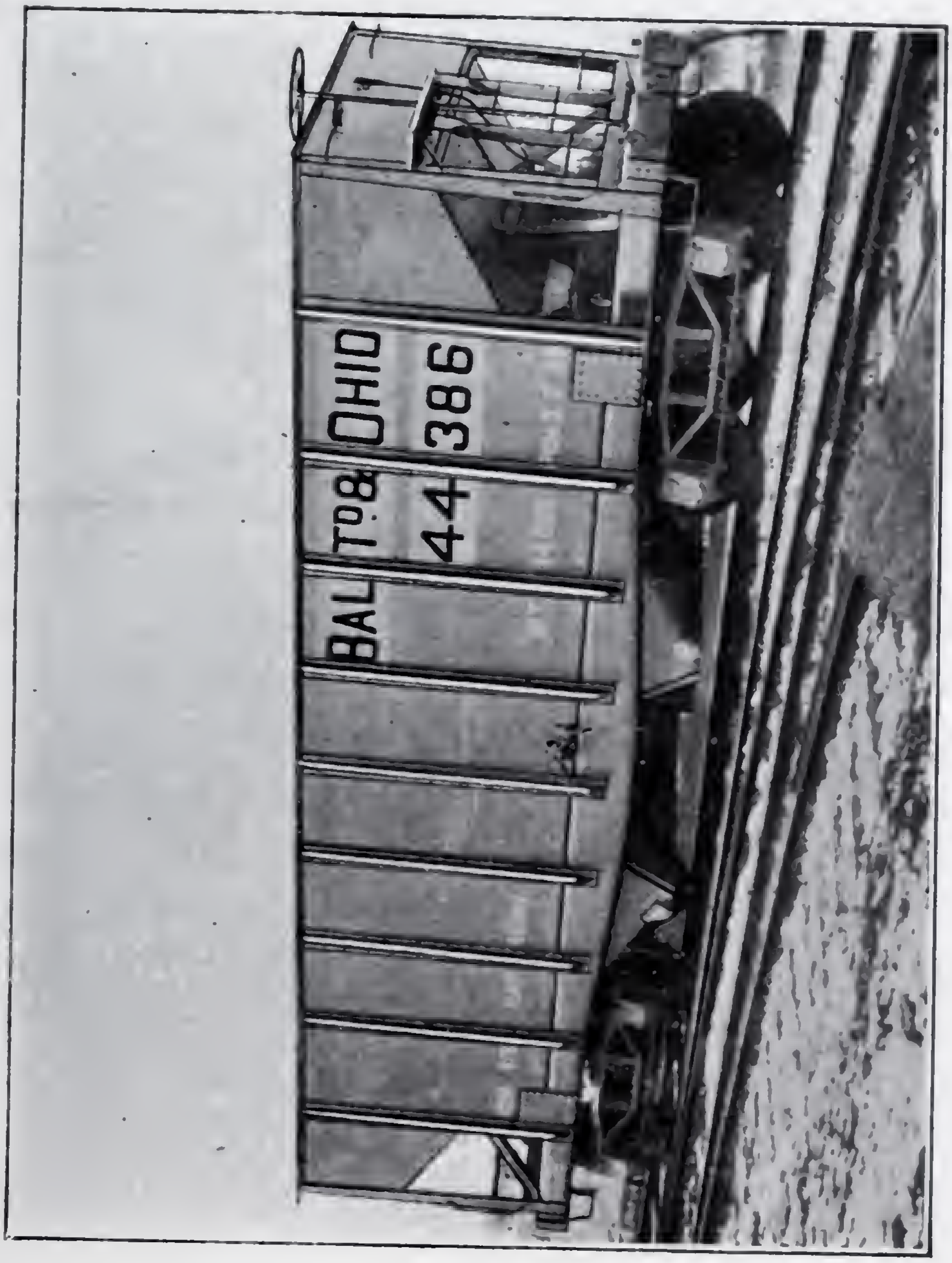


Fig. 5.

The line A A is the atmospheric line and the height a b shows the pressure required to lift the press and with it the lower die and plate to be pressed on it. From b to c the press is steadily moving upward, and at the point c the material is engaged between the dies. From c to d the piece is being flanged, d being the point where the flange has gone through 45°; this of course will be the maximum pressure required, and from here on the pressure falls to e. At e the two dies come together and the full accumulator pressure is obtained, thus carrying the line to f. The moment the press is released the pressure falls to g and the press runs down to the point h, the line gh being at a greater preasure than ab, for at this time the false bottom is forcing the piece out of the die; h being the point at which the false bottom valve is closed. The line i then returns to a, the press falling under the action

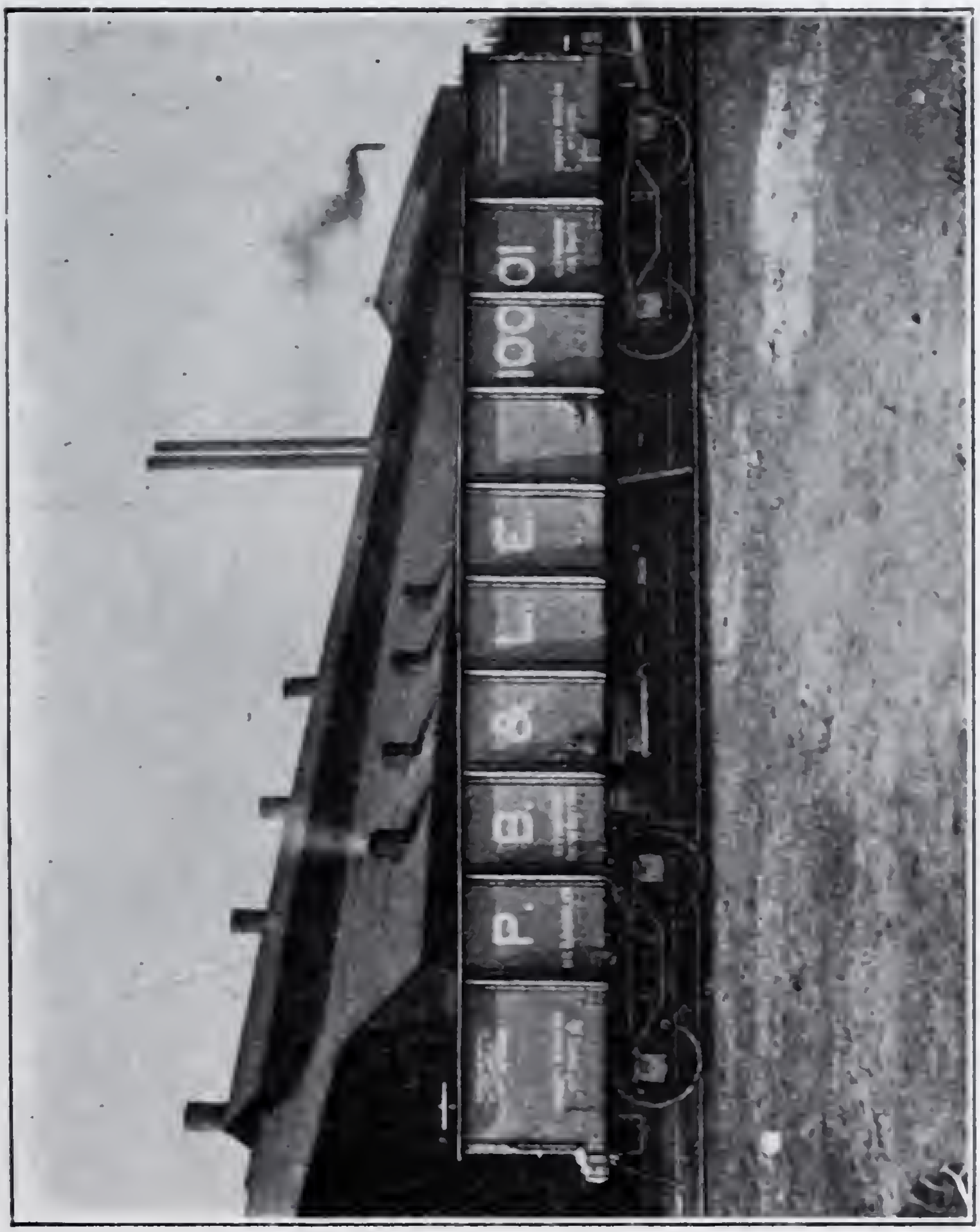


95,000 Pound Coal Car.

of gravity; and the line i being slightly lower than cb as the exaust water's friction in the pipes is overcome by the weight of the press only. From a study of this card it will be seen that the high pressure at f was not a necessary condition to do this work ; that at d being all that is absolutely required. By practice and experiment it has been found, that while some pieces of pressed work will require the full accumulator pressure, a very large number do not, as in the example taken above. Consequently if a device can be obtained, by means of which we can obtain a higher pressure than the accumulator has, it will be a saving in many ways. This is done by means of an intensifier, under the press, operated on the principle of differential areas. To go back to our indicator diagram, d would represent the accumulator pressure and f the pressure after the intensifier has been thrown in. The theoretical gain will be immediately apparent, for in one case the steam pumps must keep the water pressure constantly at f, while in the other the accumulator will always be up at the pressure shown at d. Other advantages in the way of having less pressure on the main pipe lines, less friction, etc., are readily seen.

Leaving the pressing department, the steel goes to the punches. Some few special machines are used, but mostly the ordinary single punch. The templets by which the position of the hole is marked on the piece are of the ordinary bridge type, and made generally of wood. As there must always be slight variations in pressed pieces, the ideal templet would be a flexible one, that would fit the piece closely under all conditions. If a material could be obtained like fairly hard rubber it would be just the thing. Attempts at hinging and jointing templets have so far not proved very satisfactory.

The riveting machines used are of all sizes, shapes and kinds. The greater number are actuated by hydraulic power, but air is also used. Many pneumatic hand riveters, chippers, reamers, etc., are necessary. This department is nearest to

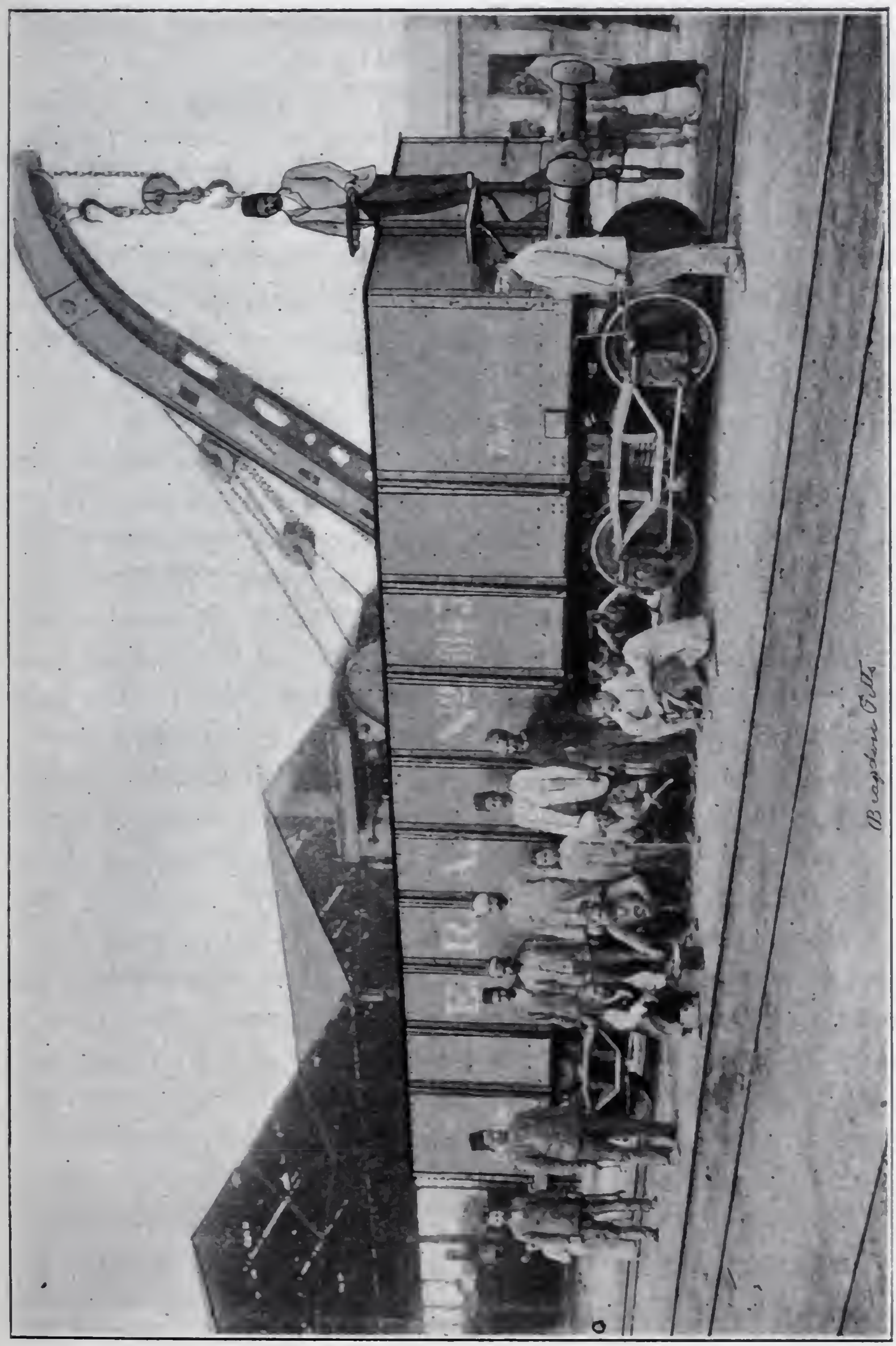


100,000. Pound Flat Bottom Gondola.

bridgework, with the machines closely spaced and plenty of overhead cranes.

In the erecting shop the large parts of the cars are fitted together by night and riveted by day, a gang leader and gang being required to fit a certain number of cars ready for the gang and leader who comes on in the morning to do the riveting; thus taking 24 hours to complete a car. I might state here that all work of all descriptions is done by piece work throughout the whole plant.

The cars lastly go into the paint shop for brake equipment, door adjustment, etc. The plant requires many additional departments, such as the truck shop, axle and wheel shop, pattern, machine and blacksmith shops; all supplying various parts but none of which contain any specially novel features.



Steel Car and Workmen—Alexandria.

Mr. Albree, who was so kind as to ask me to speak here, also asked me to say something about Egypt, where I had the good fortune to be sent some year and a half ago, with a number of steel cars that the Pressed Steel Car Company erected there. There were 100 of these cars, and all sent in one steamer; I following later by a different route. I have very little to say in regard to getting them loaded, shipped and through the custom house, as everything went smoothly.

The cars were essentially of the American flat bottom gondola type, with the exception of some few modifications. They were bought by the Egyptian government to run from the coast to Luxor, some six hundred miles up the Nile.

In order to appreciate the circumstances something of the geography of the country and of the political control, must be said. You will recollect, first, that Egypt is the "gift of the Nile," a comparatively flat country, consisting solely of sand, the only earth being brought by the river and deposited when it subsides after its yearly overflow. So that the country is a long strip of cultivated land, reaching a few miles on each side of a river, running through a vast desert. At Cairo, however, the Nile branches into two large arms and forms the large delta, it being somewhat of an equilateral triangle, about 125 miles on a side; this entire area being cultivated. Here then these cars were to run, chiefly through the Delta but occasionally up the Nile, where the conditions of grit and blowing sand are unparalleled. The journal boxes were closed with gaskets under a bolted lid, and the dust guards were a very ingenious and somewhat complicated device. The rails are laid in a curious fashion on good sized bell shaped castings some two feet in diameter; no ties whatever being used. These are on the principle of the camel's foot, hollow underneath, and buried in the sand with the large diameter down. They are laid close together, forming two parallel lines of foundations underneath the rails. The rails were simply tied together at the castings by a flat bar, something like 2 inches by $\frac{1}{2}$ inch, run-

ning across the track. As there is no rain in the country, there is no chance of the tracks settling, and they were equal to any road bed I have seen. The rolling stock is nearly as heavy as used in America, and there were a number of locomotives which Baldwin had sent. The steel cars were 100,000 pounds capacity, but the loads carried were rarely more than 80,000 pounds. The cars are used mostly for coal, but carry also cotton, various vegetables, and any general freight.

Egypt, as you know, is dominated now by the English. In the time of Napoleon the French were the masters of the country, but they have gradually been displaced by the English. So long has this mixture of Arab and Ancient Egyptian been under the control of foreign influence that I doubt their ability to rule themselves. The English quarter of Cairo or Alexandria looks as any handsome European or American city; and in the native quarter the English have instilled law and order, and any one is perfectly safe from insult in the most densely crowded streets. While the natives are tractable and a peaceful people, their manners and customs have not apparently been affected by the last few centuries of foreign influence. To-day when you walk through the small, narrow streets, sometimes thatched over to keep out the hot sun, you see again the civilization of the Arabian Nights; the color of the wonderfully different garbs, the immense turbans, long flowing robes, the donkeys decked in brass and beads, the veiled women, the camels, all seem to the stranger like a huge masquerade gotten up for his especial benefit, and not a reality outside of Fairyland. And yet the way the natives live is something astounding and appalling to ordinary ideas. The better classes live in the small, densely crowded portions, cleanliness being somewhat an imaginary quantity. The lower classes live in mud huts; goats, buffaloes, dogs, people, rats, and not the least of all these, the flea, all dwell together in the same hut, in peace and harmony, unconcious of the lapse of ages or of a desire to better their surroundings.

As I said, everything in the way of modern civilization is English; the shops are run by English, the foremen are English; a large number of natives are employed, but none ever seem to become anything better than fair workmen. As a class they are the laziest lot I ever beheld; the moment you turn your back they sit down—relax into disinterestedness, not only regarding their task, but of life in general, and hopefully trust that Allah will finish the job for them. In fact it seems as if you would need as many foremen as you have workmen, in order that each may watch his man. The ordinary native common laborer receives about 15 of our cents for twelve hours' work; and when he is one of the few who has superiority enough to be able to rivet or run some machine, he may then possibly receive the magnificent sum of 10 piastres for 12 hours' work—equivalent to 50 American cents. To be sure the way they live, 50 cents will keep them for more than one week; although the cost of living among the Europeans is possibly a little higher than here in America.

I said the Egyptian government bought the cars, but as the government is officered by English, the railroad, which is owned by the government, is entirely run by the English, and all shops connected with it. In fact the order for the cars came from London, the president of the road being an English army officer. Egypt is virtually an English colony.

I personally had very little to do with the native workmen, who speak only Arabic, and this being something of a patois. The railroad did the work of erecting the cars; their shops were in excellent form, with modern up-to-date machinery; the cars were put together in a good manner and the work well done. Some amusing things occur among the natives; it seemed that the lubricating oil given out to the locomotive engineers—some of whom are natives—was being used in such large quantities as to attract considerable notice. It was finally ascertained that this oil was being taken home as a great luxury. Large horse beans, which have that proverbial

An Every Day Sight.

leather coating, were stewed for days in this oil, until they became soft, and the whole served up as a most savory dish.

There was a story told while I was there, by one of the superintendents who had charge of the locomotive engineers. It seems that the express that runs from Alexandria to Cairo was due to leave in the afternoon, but as it approached this time no engineer put in his appearance, and the superintendent had no spare men. Finally a boy came in to say that the engineer was sick. The superintendent, however, was well aware that he was not sick but looking for a holiday. There were at this time a few cases of plague in the city and when a native contracts this disease—which is the outcome of all the squalor and filth—he is very secret about it, dreading to have the authorities find him and isolate him. The superintendent made the remark before the boy, that if the engineer was sick he probably had the plague, and that he would send for him the Black Maria, in which plague victims are taken to the hospital. The boy disappeared and the incredibly short time it took the native engineer to put in an appearance was credited by the fact he had not taken time to put on his gibbeh, or what we would term outer shirt.

I might say that the native's education is, of course, that of his ancestors during the middle ages, except that to-day there is more memory and less reason than formerly. One of their strongest traits is the love of the best of a bargain. I remember walking through their bazaars one day, being interested in these small stores, as we would call them, so very closely packed together. The men were sitting cross-legged in the small openings on each side of a narrow street; and I saw hanging up a number of opium pipes which took my fancy. They were made of cocoanuts and mounted with brass. There is no fixed price on anything in Egypt, the seller puts as high a price as possible on the article, and the buyer is supposed to put on an exceedingly small one, coffee being served and often a day or two consumed in arriving at a satisfactory adjustment

Egyptian Locomotive, Wooden and Steel Car.

—time being a secondary consideration to the Egyptian. I was new and unaware of all this, and the native was not slow to perceive it. He spoke a few words of English; and I paid him his first price without a thought, which was something like eighty piastres, equivalent to about four dollars. Some time after this I went to this same native with a gentleman whom I met in Cairo, and who had lived there several years, and had the pleasure of seeing him purchase a duplicate pipe for a value of fifty cents. When anything is to be bought it is imperative to know, approximately at least, its value and then not let heaven nor earth make you change.

I want to thank you all for your very kind attention, and if there are any questions I will be very glad to try to answer them.

A Member—Some of the photographs show wrecks. Have you you had any experiences with steel cars in wrecks?

Mr. Ely—Yes, I have seen some very severe ones; one in particular not far from Pittsburg occurred about two years ago. In it were three steel cars, one of which rolled down an embankment of about 80 feet. A long freight train which was standing still had three steel cars and caboose on the rear, and was run into from the rear by another freight train. The steel cars were all damaged and bent, but remained intact, and none of the parts became loose or wound around each other or tangled with adjoining objects. As I say, the cars preserved their entirety, although badly bent and the steel torn in many places. All were sent to shops on wrecking trucks. The caboose, which was between the striking locomotive and and the three steel cars, became two center sills with a few boards on them, all traces of a superstructure having disappeared. The wooden car directly in front of the steel cars was of the flat bottom gondola type, and this car had to be placed on a flat car, as two side and one center sills were broken.

Mr. Hirsch—Was it much of a job to straighten those cars out?

Mr. Ely—No, but it is generally cheaper to cut the pieces off and put on new ones.

A Member—Are these cars fitted up with interchangeable parts? i. e. can you replace the damaged piece?

Mr. Ely—Yes, the piece can be replaced.

A Member—Have you applied any steel construction to passenger cars?

Mr. Ely—No, we have not done so, but I have no doubt that in the course of time it will be done, especially for the underframing. Of course the great question of steel is the weight, and if we make passenger cars heavier than the wooden cars used at present we have no increased weight to carry in them, so we do not save anything in theory.

Mr. Fisher—Gentlemen: you have heard a very interesting and instructive talk, and I am sure we are very much indebted to Mr. Ely for it.

A vote of thanks was tendered Mr. Ely by the Society, for his excellent talk.

Mr. Albree—I want to say, we again had to go outside of the Society to get a man to give us a paper. I think it a very great reflection on our Society that the committee has not been able to get a paper from one of our own members. I want to call the attention of the Society to the fact that if we cannot get a good paper from the members of the Society, we can get good papers from men who are not in the Society.

I want to express my appreciation of the excellent discourse we have listened to this evening.

Mr. Scott—I do not know whether we ever had a chairman of the program committee who was not forever kicking, or not. At the last meeting he had to give a paper himself, one of the best we have had, now he had to go outside of the Society to get a first-class paper, and also got a new member.

Mr. Hirsch—I would like to ask Mr. Ely one question;

do you find much difficulty in getting names for all the parts?

Mr. Ely—Oh no, we coin names for them.

Mr. Johnson—In the remarks Mr. Ely made he mentioned something about whether these cars would rust or not. I would like to have him tell me whether they would stand fire and water both. These cars are used in shipping coal to the lakes and bringing back ore, and in the winter when they reach the mills it is a solid mass.

The mills have adopted the method of building fires under the cars to thaw them out, and when they get back to the railroad they are not in the same condition.

Mr. Ely—Well, I cannot say as for that. The car is certainly not a storage house, and if you take a wooden car and do the same thing with it you will find that the result will be greatly in favor of the steel cars. Under ordinary circumstances, they ought to last 30 or 40 years, with any kind of care.

On motion the Society adjourned at 10 P. M.

Reginald A. Fessenden,
Secretary.

CHEMICAL SECTION.

June 21, 1900.

Regular meeting of the Section at 410 Penn Avenue, called to order by the Chairman, Jas. O. Handy. Seven members present.

Minutes of previous meeting read and approved.

Notes on recent methods of analysis and references to new books were then read by the Chairman. After discussion the meeting adjourned at 9 p. m.

Geo. O. Loeffler,
Secretary, C. S.

Engineers' Society of Western Pennsylvania.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The 107th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's house, 410 Penn Ave., Pittsburg, Pa., Tuesday evening, September 18, 1900, thirty-one members and visitors being present. The meeting was called to order at 8.35 o'clock by the President, Mr. W. A. Bole.

The minutes of the previous meeting were read and approved.

For the Board of Directors, the following applicants were reported as passed and to be voted for at the next regular meeting:

EDWARD HOERLE, - -	Superintendent of Construction, Duquesne Steel Works and Blast Furnaces. 5649 Second Ave., Pittsburg.
FRANK CLARENCE NEWELL,	Electrical Engineer, Westinghouse Air-brake Co. (in charge of the Electric Brake Dpt.), 423 Ross Ave., Wilkinsburg, Pa.
W. H. H. GINDER, - -	Chemist, American Sheet Steel Co., Vandergrift, Pa.

The following gentlemen were balloted for and duly elected to membership:

SUMNER B. ELY, - - -	American Sheet Steel Co., Vandergrift, Pa. House, 925 Bidwell St., Allegheny, Pa.
HOMER E. WHITMORE, -	General Engineer, With E. K. Morse, Carnegie Building, Pittsburg, Pa., House, 511 Larimer Ave., Pittsburg, Pa.

For the Reception Committee Mr. Beutner reported that they had not done anything so far and a motion was passed by the Society instructing the Reception Committee to arrange for a smoker to be held at an early date.

For the Library Committee Mr. Hirsch reported that they had done some work during the summer; that the stock of books had been arranged in very good order, and that those that were deemed of special value were to be bound, but that the Committee were of the opinion that there were some of the books which it would hardly pay to have bound until the Society could better afford it.

For the Financial Committee, Mr Johnson reported that Mr. Davison, as Chairman, had intended to make a report, but was absent, and that he could not make a report in Mr. Davison's absence.

For the Pan-American Committee, Mr. Albree reported that they had received some letters on the subject but had no definite proposal.

Mr. Bole stated that there were two deaths among the members of the Society since last meeting: One Mr. James Hemphill, one of the oldest members of the Society; the other, Mr. William A. Herron, one of the oldest residents, and that as it was the usual custom in such cases to appoint a committee to prepare a suitable memorial, he would request the Secretary to notify the following committees: In the case of James Hemphill, Wm. Metcalf and Julian Kennedy; in the case of W. A. Herron, Col. Roberts and W. L. Scaife.

Mr. Bole stated that the American Society for the Advancement of Science held a meeting this summer and Professor Brashear asked him to extend an invitation for the Society to hold its meeting in 1901 in Pittsburg, which letter he wrote, and received the following reply:

WASHINGTON, D. C., July 11, 1900.

MY DEAR SIR:

In acknowledging receipt of your letter of 22d of June, conveying on behalf of the Engineers' Society of Western Pennsylvania an invitation to this Association to hold its meeting in 1901 in Pittsburg, it gives me pleasure to inform you that, although the Association was practically pledged to go to Denver in 1901, the decision was reached that it will be to the best interests of the Association to hold its meeting in Pittsburg in 1902.

Yours very truly,

L. O. HOWARD.

MR. WM. A. BOLE,
President, E. S. W. P.,

Mr. Bole also stated that he had received a communication from Gustave Kaufman who was elected to the office of Director, who stated in a letter, dated June 19, that owing to his absence from the city, he was compelled to resign as Director; and that as the Board of Directors was empowered to elect a member to fill the vacancy until the Society at large should take action and elect a successor, the Board, in view of this authority, had seen fit to elect Mr. C. B. Connelly until it was the pleasure of the Society to elect a successor, and if it was satisfactory to the Society to allow this action to stand, Mr. Connelly would act as director until the regular election in January.

MR. JOHNSON—Moved on the part of Society that they indorse the action of the Board and that Mr. Connelly be considered a Director until the next election. Motion carried.

The next in order was the reading of the paper of the evening by Mr. W. E. Snyder, entitled, "Blowing-Engines."

BLOWING ENGINES.

BY WILLIAM E. SNYDER, M. E.

Historical Sketch.

A blowing machine—French, "*Machine Souflante*"; German, "*Geblasse Machine*"; Italian, "*Machina Soffiante*"; Spanish, "*Bofeton,*" is any apparatus used for forcing a continuous current of air.

Among the multitude of uses to which such machines are put, may be mentioned: to supply vital air to close, fetid places, such as mines, wells, cisterns, holds of ships, etc.; to supply currents of warmed, cooled, moistened or medicated air to public buildings; to supply a drying atmosphere in lumber, meal kilns, powder mills, etc.; to assist in the evaporation of liquids by carrying off the vapor; to assist in the dispersion of liquids in atomizers and in some ice machines, and to supply a strong, steady blast for smelting, smithing, foundrying and in the Bessemer steel process. It is with blowing machines used for iron smelting and for the Bessemer process that this paper is concerned.

The first blowers in use were a primitive form of bellows made of the skins of wild beasts. In 1550 a wooden bellows was made, which consisted of a box which slipped into another, fitting closely, and was provided with the proper valves for admitting and discharging the air. About 1621, Fannenschmid, of Thuringia, invented a blower which worked upon a different principle. This was a flat vane, which was fixed to a shaft and moved with an oscillating motion in a sector-shaped box. A somewhat similar invention was made some time afterwards, which consisted of two flat vanes fixed on an axis about thirty

degrees apart. The axis was given an oscillating motion and the vanes moved backward and forward in a semi-cylindrical box. A valve of ingress was provided in the bottom on each side of the box. Also suitable valves in the vanes, and a pipe, leading from the top of the case, to carry off the air. This was the germ of what afterward developed into the modern fan and rotary blower. Then the apparatus having the principles of the modern air cylinder began to be introduced. The earlier types embodied the elements of cylinder and piston, the principal differences between them being in the means employed in communicating motion to the piston, and in the methods used to secure a comparatively uniform blast pressure.

The first blowing cylinders were single-acting. Sometimes two were coupled to the same shaft with cranks at 180 degrees, or three were coupled to one shaft with cranks at 120 degrees. The shaft was usually driven by water power. To secure as uniform pressure as possible, the air was driven from these cylinders into what was called a "water regulator." This was an air-tight box or tank, inverted over water and weighted down. The air, on being forced into this tank, was caught in the same manner as gas is caught by displacement. The weight on the tank was adjusted to produce the pressure required and the tank, by rising and falling, maintained this pressure approximately constant. This method was unsatisfactory in warm weather, as the warm air, coming into direct contact with the water, became so heavily saturated as to render its use extremely detrimental to the proper heating of the furnace.

Then another change was made. A wooden cylinder or tank of about twice the capacity of the blowing cylinder, and containing a weighted piston, free to slide up or down, was adopted. Sometimes this was used in connection with the water regulator, but oftener it was used alone. The air was pumped into this cylinder under the weighted piston. This piston moved up or down, regulating the pressure similarly to

the weighted tank in the water regulator. In case of either the use of this cylinder alone or in connection with a water regulator, its principal defect was that it was too small. A cylinderful of air exhausted rapidly into it would throw the movable piston higher than was necessary to make room for the incoming air. In falling, it would obtain some kinetic energy which would have to be absorbed before the piston came to rest on its cushion of air. This produced slight rarefactions and compressions which made the blast pressure very unsteady.

The next improvement was the adoption of a large air chamber into which the cylinders discharged their air. These were from twelve to thirty times the volume of the air cylinder. The elasticity of the air acted to regulate the discharge and maintain the pressure.

In 1835 double-acting blowing cylinders began to be used. Two cylinders with cranks at 90 degrees were coupled to the same shaft. Large mains were used to take the place of the air chamber.

Large beam engines began to be built in England early in the present century, patterned after the immense Cornish beam pumping engines of that time.

In 1848, Archibald Slate, of England, endeavored to replace these ponderous, slow-moving beam engines by a light, high-speed type. He reasoned that a shorter stroke would give a steadier air pressure. He was led to consider the effect of short-stroke blowing engines by using compressed air in a common slide-valve engine. He rightly conjectured, further, that if the piston stroke were short the air valves would have to be actuated by a positive mechanism. Previous to this the air valves had been automatic, depending upon the pressure of the air for their action. In pursuance of his ideas, he constructed two horizontal engines coupled to the same shaft. The principal dimensions of these engines were: Diameter of steam cylinders, 10 inches; diameter of air cylinders, 30

inches; stroke, 24 inches. These were to run at a piston speed of 640 feet per minute, or 160 revolutions, and blow 3.5 pounds per square inch blast pressure. No steam pressure was given, but if the M. E. P. of the air end is taken to be 3.5 pounds, each engine would develop about 48 H. P. at the air end. Assuming an efficiency of 90 per cent. between the air and steam ends, there will be about 53 H. P. to be developed at each steam cylinder. For the given size of cylinder and piston speed, this would require about 34 pounds M. E. P., which is probably reasonable, as the boiler pressures of that time were low. For the given diameter of air cylinder and stroke, the piston displacement would be 3,000 cubic feet per minute for each engine, or 6,000 cubic feet for the double engine.

As an example of the beam blast engines, which were much used in England in the early part of this century, there follows a description of one built for the Dawlais Iron Works, in England, in 1851. The full description of this engine, together with a discussion of its merits, etc., is given in the report of B. I. M. E. for 1857, page 112.

It was, in principle, a large beam, cast in two parts and supported by a pivotal axis, about which it oscillated. On the one end of this beam the rod of the steam cylinder was coupled, in this case, by a large oak connecting rod, strapped with wrought iron. The fly wheel was coupled to the same end by a similar rod. The piston rod of the air cylinder was attached to the other end of the beam by another oak connecting rod. This beam was 40 feet 1 inch between centres, and its gross weight was 44 tons. The diameter of the air cylinder was 144 inches and of the steam cylinder 55 inches. The stroke of the air cylinder was 12 feet and of the steam cylinder 13 feet. This difference in the length of the stroke was caused by the connecting rods from the cylinders being attached at unequal distances from the supporting axis. The blast pressure was 3.5 pounds and steam pressure sixty pounds, with cut-off at one

third stroke. It was run at twenty revolutions per minute, giving an air displacement of 44,000 cubic feet and requiring the development of 650 H. P. at the steam end. The fly-wheel was 22 feet in diameter and weighed 35 Tons. The gross weight of this ponderous machine was over three hundred tons. The English practice of that time, according to the discussion following the above article, was to put in three times the weight of cast iron actually needed.

Though this unwieldy machine was built in 1851, yet one almost similar in design is described in "Engineering" of, February 27th, 1880—built almost thirty years later. This engine was designed by Mr. Alfred Trappen, Chief Engineer of Die Markische Machinenban Anstalt of Wetter-on-the-Ruhr. The same walking beam plan is used, but the beam is lighter than the English make—being built of plates and angle bars. This engine, however, is a compound, the steam cylinders being connected to one end of the beam and the air cylinder to the other. The piston rods are provided with large guide blocks to avoid the extra wear of parallel motion. The common flap valves are used for the air. The packing of both air piston and valves is felt, mounted on leather. The steam valve is simply a common slide—one valve controlling the steam in both cylinders. The principal dimensions of this engine are:

CYLINDER.	DIAMETER.	STROKE.
High Pressure	32.875 inches	74.125
Low Pressure	55 56 "	98.81
Air	102.94 "	102.94

Diameter of fly-wheel is 24 feet 8.5 inches and its weight is 30 tons. Its speed was 13 revolutions per minute at which the air displacement is 7800 cubit feet. The steam pressure for which it was designed is 50 pounds; cut-off at .7 stroke with five expansions. Blast pressure 5.7 pounds. (The description of the above engine is given to show how very little the general design of blowing engines changed from 1850 to 1880. Either of the above engines occupied as much space as is now available for an entire engine house at same plants.)

In 1855 the East Indian Iron Company of England was obliged to have several blowing engines made which had to be transported considerable distances across the country to the works where they were to be used. This precluded the possibility of using the immense beam engines so comman at that time in England. The engines which, were finally designed and built for this Company are described in a paper read before the B. I. M. E. by E. A. Cowper and given in their reports for 1855, page 154.

These engines are built on the general plan of the present modern type of vertical blowing engines. They are claimed to have been the first engines of this type ever designed and constructed, but the Chairman of the meeting before which, the paper was read, said he had seen an engine embodying almost the same principles of vertical construction, at the French Exhibition previous to 1855. (This would seem to indicate that the vertical blowing engine was first invented by French engineers.)

In designing these engines the special aim was to secure lightness and they did not weigh more than one tenth to one fifth of the weight of the ordinary blowing engine of that time. Tho designer claimed that the most essential element of an engine to produce a steady blast, is a short stroke. He further believed that for the proper working of a short stroke blowing engine, the air valves should have a positive movement and not depend on the air pressure for their operation. He therefore moved the air valves by a mechanism which was controlled by an eccentric. Both the style of this engine and the positive movement of the air valves are improvements over the old type of beam engine. The principal dimensions of these engines were as follows: Diameter of air cylinder, 30 inches; diameter of steam cylinder, 10 inches; stroke, 30 inches. They were run at 80 revolutions per minute or a piston speed of 400 ft. The steam pressure was fifty pounds and cut-off at one half stroke. Air displacement is 1975 cubic feet per minute.

In the discussion which followed the reading of this paper it was said that the fly-wheel produced unsteady blast pressure because it caused the main shaft to revolve with uniform angular velocity and this, in turn, causes the piston to move irregularly. Also that the fly-wheel was advantageous only when two engines were coupled to the same shaft. This shows the views that were held by the advocates of the old beam engine in which the energy was stored and re-stored largely by the ponderous walking beam.

A somewhat peculiar cross compound vertical blowing engine constructed by Messrs. Klein Brothers of Dahbuck is described in "Engineering" of October 29th 1880. The engine was somewhat like the present modern vertical compounds. It was condensing, the air and water pumps being attached to the cross-head and one of the iron columns which supported the air cylinder together with part of the bedplate was used as a condenser.

RESUME.

Blast, blown by machinery, was not utilized in iron smelting until after 1700. The steam engine had not developed much before the time of Watt, which was about 1750-1775.

An English engineer is said to have erected blowing engines at the Carron Iron Works in 1760. From this time down to about 1850, only the large beam engines, or very small short-stroke engines were used. About the middle of the present century the vertical type began to be used and from that time on it has developed to be the favorite of iron smelters.

The general design of blowing engines has changed considerbly during the past twenty years. Many changes in detail construction have not been improvements.

There has been a tendency to adopt average views concerning dimensions, etc. Thus blowing engines having a stroke of from two to three, or from ten to twelve feet, were formerly quite common. Now, none such are built.

The beam engine still seems to be used in some places, but its use is the exception. Altogether the development of the blowing engine has equalled that of the motor engines.

Air Compression by Blowing Engines.

The function of the blowing engine is to supply oxygen for combustion.

The more oxygen supplied per unit of power developed, the more efficient is the engine, commercially.

By the very nature of the atmosphere from which the engine draws its supply, it is compelled to pump, in addition to oxygen, quantities of aqueous vapor, nitrogen and small amounts of some other gases, depending on conditions.

These gases exert a deleterious rather than a beneficial effect on combustion, in that they contribute nothing toward generating heat, but carry heat away wastefully when they are discharged.

The air is blown into a system of piping with discharge openings in some part, and the relation of the area of these discharge openings to the volume of air blown per unit of time will determine the pressure which must exist in the system in order to force the air out as fast as it comes in. To force the air into the system it must be compressed up to, or slightly above, the pressure existing in the piping. This requires that work be done upon it, and the most unsatisfactory part of the whole matter is that the inert gases must be compressed along with the oxygen, involving an absolute waste of a large percentage of the power developed. This is one very important difference between blowing engines and air compressors. Nitrogen is just as efficient for the transmission of power as oxygen, but not as efficient in a blowing engine This, of course, cannot be remedied, owing to the intimate mixture of the constituents of the atmosphere, but weight of oxygen or air, and not volume, should always enter into all blowing engine calculations.

The compression of air and the efficiency of the air cylinder may probably be better discussed and explained by reference to the theoretical compression diagram shown in Fig. 1.

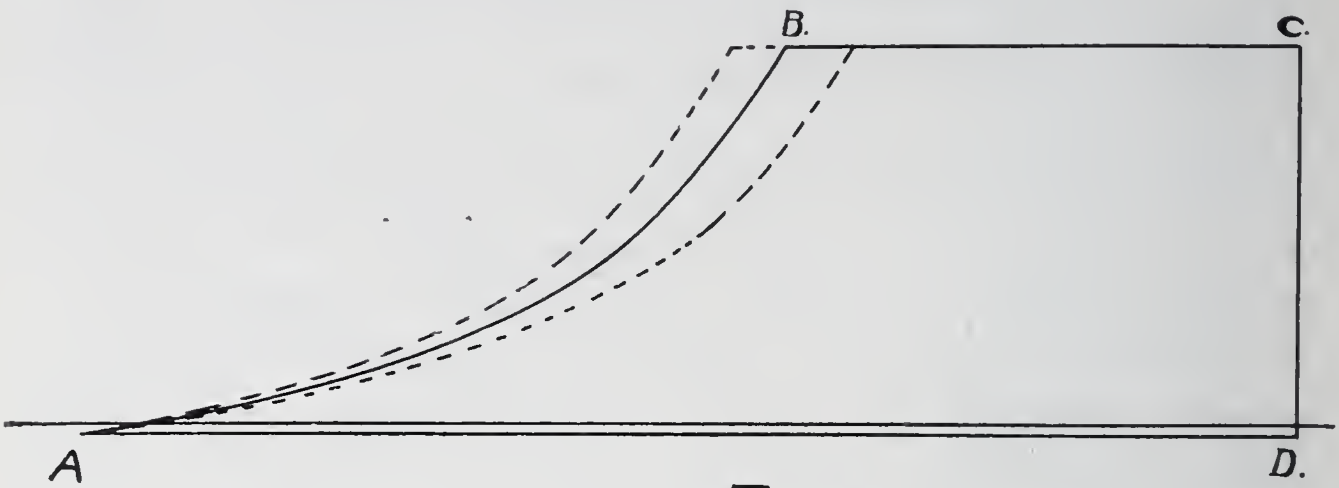


FIG. 1.

If the heat generated by compression all remains in the air, the compression is adiabatic; if it is all abstracted as fast as it is generated, it is isothermal.

At the point A on the card the piston is at the end of the stroke, with the cylinder filled with air at practically atmospheric pressure. When the piston moves forward on its next stroke this air will be compressed, indicated by the curve A B. This curve may be anything between an isothermal and an adiabatic. In a number of blowing engine cylinders which the writer has investigated, on which there was no provision for carrying off heat, the curve approached the adiabatic in form very closely.

At B the discharge valves open and the air is discharged into the receiver while line B C is being traced. At point C the piston is at the extreme end of the stroke, and as soon as it starts in the opposite direction the pressure drops to that of the supply, and a fresh volume is drawn in while line D A is being traced. This, of course, assumes that there is no clearance space.

The amount of oxygen pumped per stroke depends on the efficiency of the air cylinder and on the temperature. Minimum clearance, tight valves and ample port area render maximum cylinder efficiency.

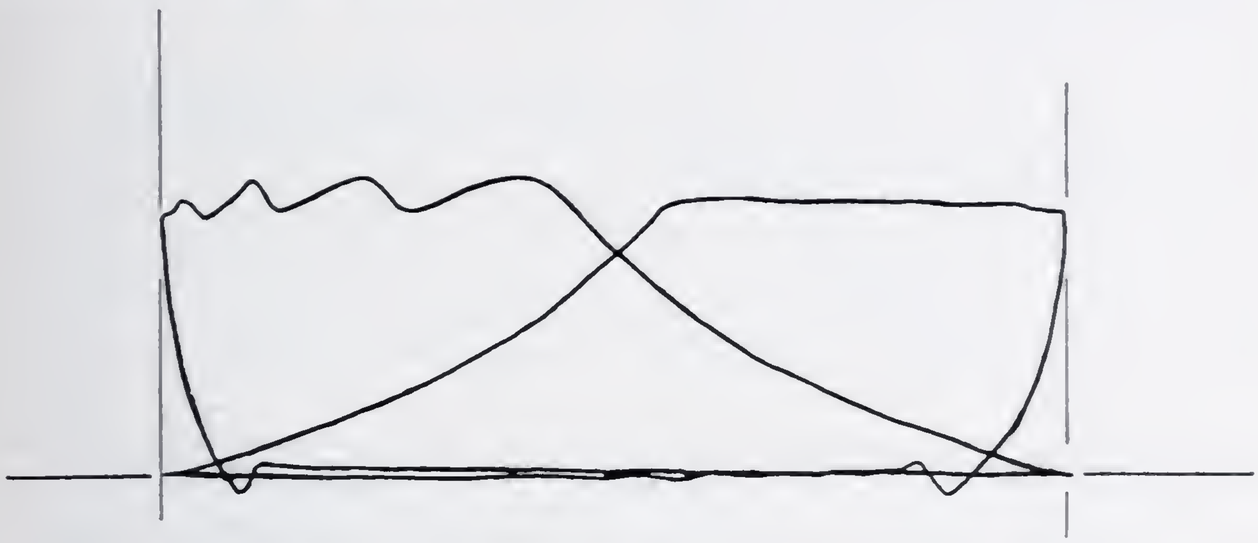


FIG. 2.

Fig. 2. Shows a pair of diagrams taken from a blowing cylinder with large clearance spaces. The clearance as calculated from the diagrams is about 6.5 % on U. E. and 4.7 % on L. E. The loss in capacity as shown is 10.3 % at upper end and 7.3 % at lower end—an average of 8.8 %.

The clearance spaces being large, leave a large volume of air between the piston head and the discharge valves at the end of the stroke. This air is at terminal pressure and when the piston starts on the next stroke it expands down to the pressure of the supply and of course increases in volume, thus allowing only a partial cylinderful to be drawn in for the next stroke.

The line at the end of the diagram should drop down straight as shown by the vertical line, and on diagrams from engines with very small clearance spaces, this line is practically straight as shown on Figs. 11 and 17.

The admission ports should be of such shape that the air flows into the cylinder in streams of largest possible cross section. The air should have a direct passage to the port and

come in contact with as little metal as possible to prevent heating before compression commences.

The ports should have ample area to permit of the engine being run up to 500 feet piston speed without the formation of vacuum in the air cylinder.

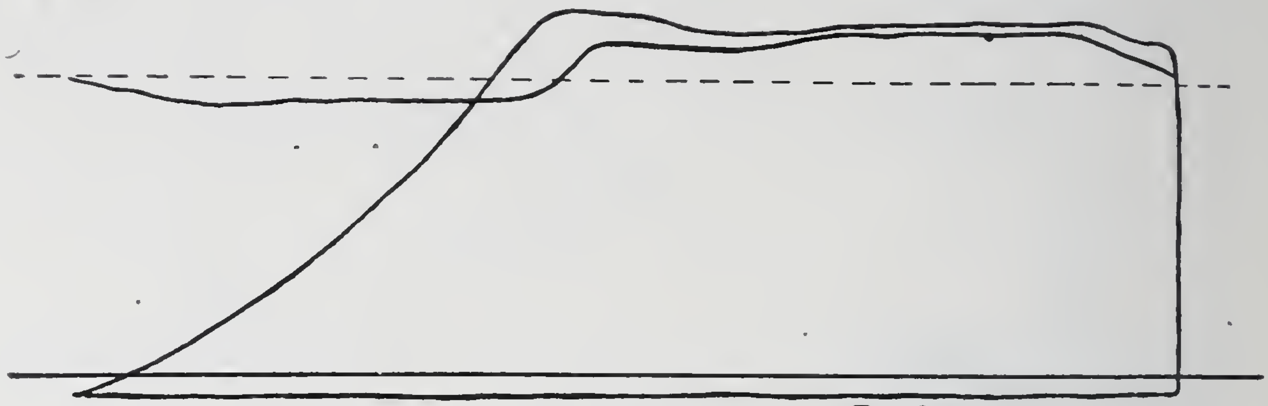


FIG. 3A

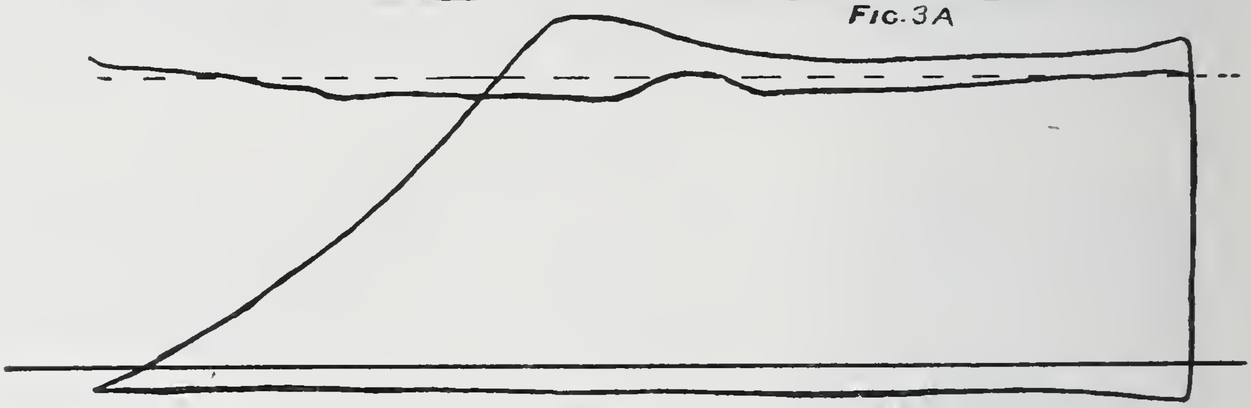


FIG. 3 B.

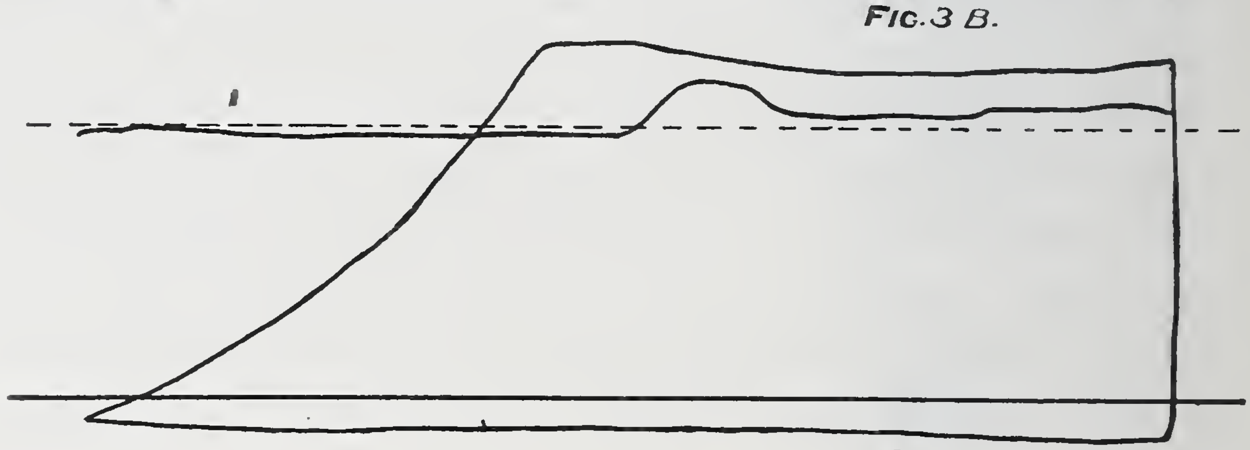


FIG. 3 C.

The effect of restricted port area is shown by the diagrams of Fig. 3. These diagrams are from the same end of the cylinder but running at different speeds. The diagrams from the other end were practically the same and were not drawn in.

The following table shows the losses due to restricted admission ports and excess discharge pressure for three different speeds. The loss due to excess discharge pressure is vari-

able and was affected by conditions of discharge valves and variation of the receiver pressure.

Revs. per min.	Vacuum Loss. U. E.	L. E.	Mean.	Excess Press. Loss. U. E.	L. E.	Mean.	Fig.
25	6.5%	8.2%	7.35%	12.7%	10 0%	11.35%	3A
35	8.3%	6.1%	7.25%	7.9%	4.7%	6.3 %	3B
45	12.2%	9.8%	10.50%	14.5%	9.6%	12.1 %	3C

The table as well as the diagrams show the increase of loss due to vacuum as the speed increased. In an engine with ample ports the admission line of the diagram will very nearly coincide with the atmosphere line showing the very small difference of pressure required to make the air flow into the cylinder.

As the air cylinder is always of large diameter, a very slight varation in pressure will make a very considerable change in the power required. All such matters are of more economic importance than a casual examination of the diagrams would indicate.

Another very fruitful source of waste of power is restricted discharge ports. This makes necessary a great difference in pressure between the air in the cylinder and that in the receiver, in order to cause the air to flow through the ports.

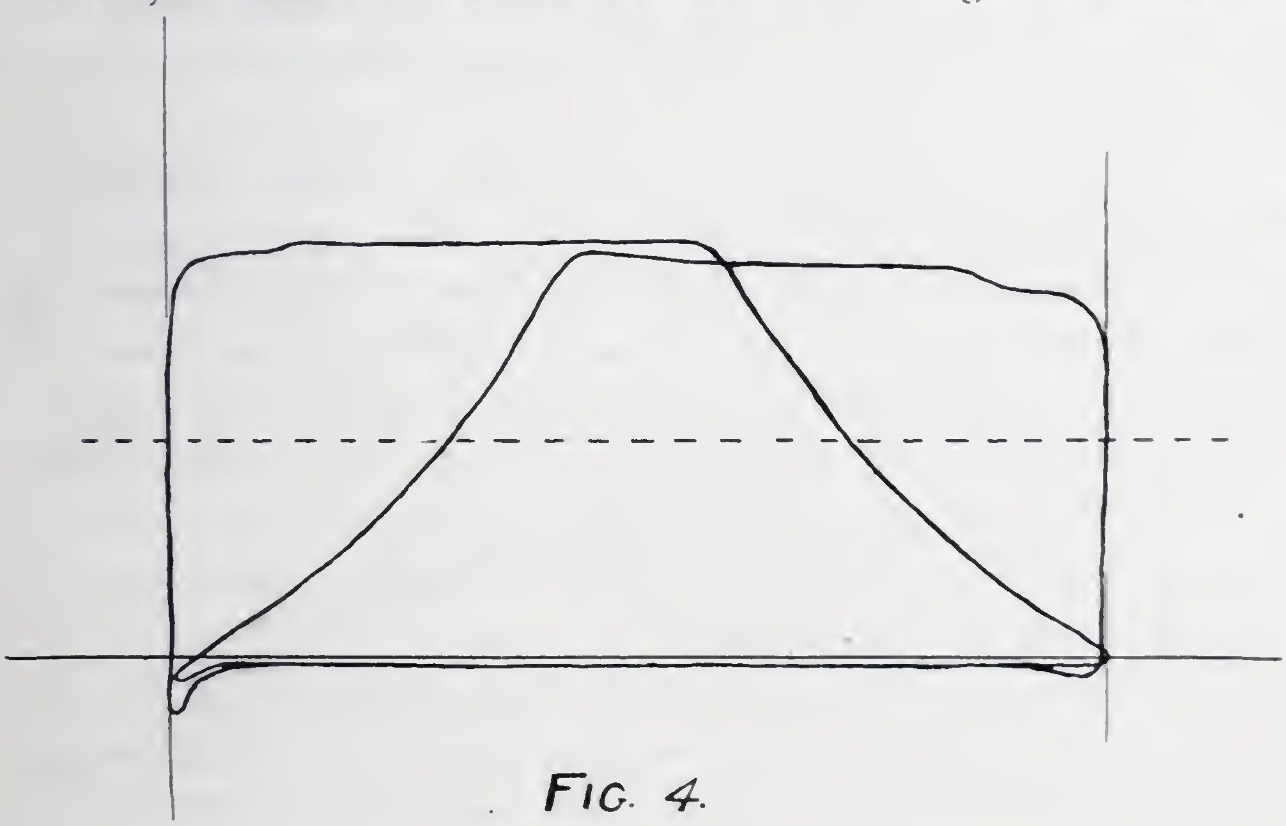


FIG. 4.

The diagrams shown by Fig. 4 illustrate this so forcibly that comment seems hardly necessary.

The dotted line shows receiver pressure, and the area between that and the delivery line of the diagram shows power simply wasted.

The actual wasted power due to this cause was 122 I. H. P. for the upper end, and 105 I. H. P. for the lower end, making a total of 227 I. H. P. required to force the air through the discharge ports, or 38.6% of total steam I. H. P. developed.

The effect due to leaking valves is so evident that no discussion is needed. It is assumed that the valves are kept tight, as that source of waste is within the control of the ordinary engine runner.

One other item of waste demands special mention, and that is the almost universal custom of drawing the air supply from the engine room after it has been heated by contact with steam pipes, heated metal surfaces, etc. On this point Mr. Frank Richards in his book on compressed air says: "Commission brokers must live and thrive on commissions of $\frac{1}{16}$ to $\frac{1}{8}$ of one per cent., but your practical man looks with contempt on savings of 1 or 2 per cent." Certain it is the cooler the air when drawn into the cylinder, the more economical will be the compression.

So far as atmospheric conditions are concerned, the amount of oxygen blown per revolution is a function of the temperature alone. Humidity may effect the combustion which the oxygen promotes, and interfere with furnace action, but it does not change the weight of oxygen contained in one cubic foot of space. Nothing but a change of the temperature of the air can do that.

The diurnal changes of temperature and those due to change of seasons must cause great variation in the weight of oxygen blown per revolution.

In all blast furnace practice it is the endeavor to get the furnace into the best state of working, and then maintain all conditions uniform. To obtain this uniformity the amount of

oxygen discharged per stroke for each engine should be known, in order that the air may be controlled with the same certainty that the burden is regulated. To do this correctly a separate table must be made for each engine, making proper correction for clearance, etc. and referred to a weight of oxygen as a basis. These tables must take into consideration variations in quantity of O pumped, due to temperature changes.

To illustrats the actual effect produced by changes of temperature let us make the following assumptions: Amount of air required per minute by one furnace 40,000 cubic feet. Average temperature for one hour in winter, 0 deg. Average temperature for one hour in summer, 100 deg. Average carbon in coke 89%. Average analysis of furnace gas CO_2 12%, CO 22%, O 2% and N etc. 63%. Neglecting the effect of the H these assumptions show 1.8 lbs. of O required per lb. of coke. 40,000 cubic feet of dry air will weigh under the assumed winter conditions 3452 lbs., and under the summer conditions 2840 lbs. This makes a total difference in the weight of air blown under the two conditions, of 36,720 lbs. per hour. In other words 8,666 lbs. of oxygen more will be blown in winter than in summer by the same volume. Since 1.8 lbs. are required per lb. of coke, 4,814 lbs. of coke more per hour can be burned with the same volume when the air is cold than when it is warm.

However this is a matter which might better be left with the metallurgist to decide. Still it seems to the writer that the practice of blowing furnaces on a basis of displacement contains many inaccuracies which militate against successful operation.

Practical Operation.

It is not the purpose of the writer to attempt to lay down rules or give methods to be observed in the operation of blowing engines. It is rather to discuss some particular points to be observed by the men who have charge of such engines, and

especially to endeavor to correct some erroneous ideas regarding proper valve adjustment. The exceedingly small amount of engineering literature extant on the subject of blowing engines may in some measure account for the ignorance on this subject; for certain it is that the sum total of actual information available from technical publications is very meager indeed. There seems to be only two explanations for this ; either very little is known, or else the men who do know are content to let others experiment for themselves.

The writer has given this subject considerable attention both theoretically and practically, and writes from a varied experience, some of which was exceedingly exasperating.

Probably no type of engine is subjected to more abuse by its operator than is the blowing engine. One reason for this is that the so called engineers of the engine room are not engineers, and do not understand any of the scientific principles underlying the compression of air by the expansion of steam. Another reason is that a modern blowing engine has more parts susceptible of adjustment about the two sets of valve motions required by the steam and air cylinders. This affords a wide field for "original research and experiment" by the men in charge without much fear of apprehension.

In the blowing engine, as in other engines, pounds and knocks develop from seemingly no cause. These are magnified by the huge cylinders and massive proportions of the machine so that they become exceedingly annoying and cause concern. So soon as such a trouble develops many an engineer will sieze his hammer and wrench and go after that pound. He has learned by experience that the valve motion is the most vulnerable point. Here he can produce the greatest effect in the least possible time and he attacks it at once. He lengthens one rod, shortens another, tightens a nut, puts in a liner, etc., all of which may or may not produce any visible effect. He may then "put her back where she was," in other words reverse all the changes he has made—so far as his memory will allow

him—and proceed to start out again in some other direction. The pound may be eventually stopped by such methods, but in addition, some change may be made, which, while it gives no visible or oracular demonstration in the running of the engine, may do a vast deal greater harm than the original pound. This is no fanciful exaggeration, but actual conditions which prevail in some engine rooms, accessible in the length of time it requires to read this paper.

Of course any sensible man with any knowledge whatever of the subject will agree that the proper procedure in such a case is to indicate the engine, and see if the valve adjustment is correct. If it is not, correct it. Then if the pound still continues, go after it elsewhere but let the valves alone.

The question af setting valves on blowing engines is a bone of frequent contention and causes no end of discussion. The proper way to do is to set the valves carefully and correctly by the marks put on them by the makers, and then indicate the engine and adjust the valves.

The setting by the marks must be done accurately throughout, or it is simply time wasted. Many men put the engine on the dead center, by guessing at it, with the idea in mind that the crosshead moves so slowly at that point that any little error off the center, one way or the other, will make no material difference, and utterly oblivious of the fact, that with the Corliss valves as ordinarily set on blowing engines, the eccentric is nearly 90 degs. ahead of the crank, and when the crosshead is moving the slowest, the eccentric is moving the fastest. Thus a very slight error in the position of the crosshead would produce a very decided change in the position of the eccentric, and throw the whole setting out. It is also the practice to set one end, and to assume that the other is right. This is also wrong.

To illustrate the reliability of setting valves by marks alone, the diagrams shown by Fig. 5 are given. These valves had been set some time previous to indicating, by the man in charge, exactly to the mark. After these cards were obtained

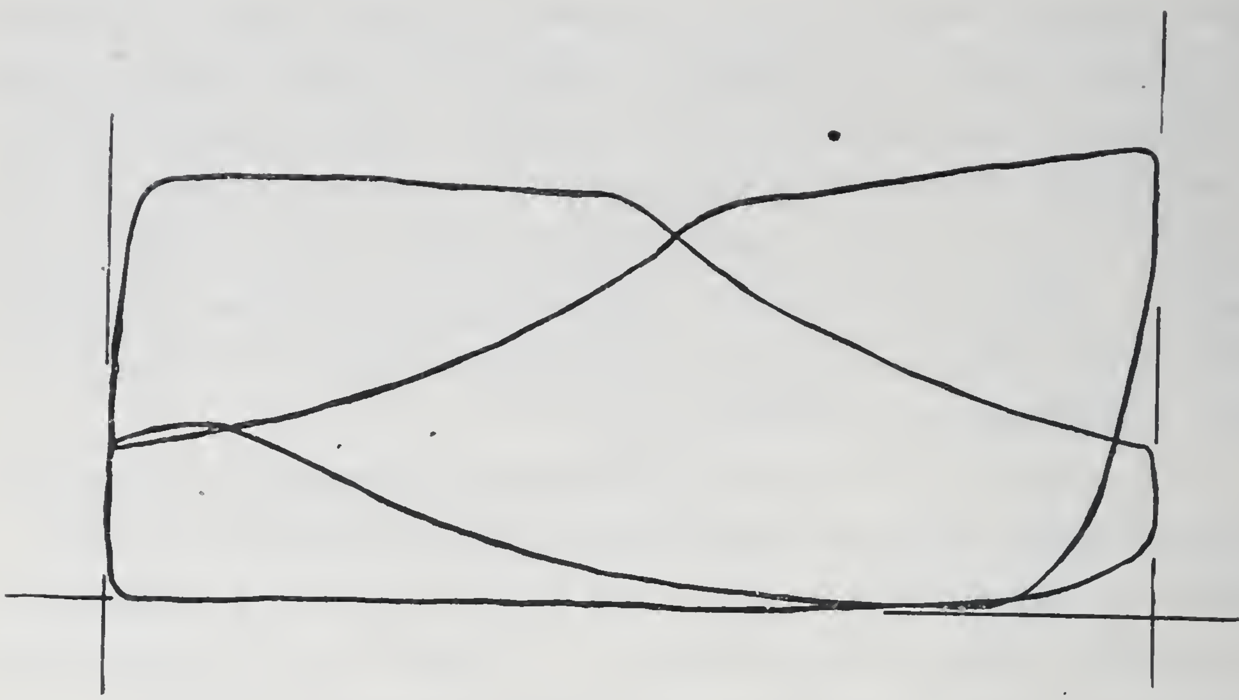


FIG. 5.

the bonnets were taken off the valves and the entire setting verified by the writer. The valves were then removed from their chambers, and some of the marks found to be wrong. The cards show conditions that would never knowingly be permitted to exist in any engine room, having a compression on one end of about 66 lbs. per sq. in. Fig. 6 shows the setting of Corliss valves also by marks. The conditions are so manifestly wrong that comment is unnecessary.

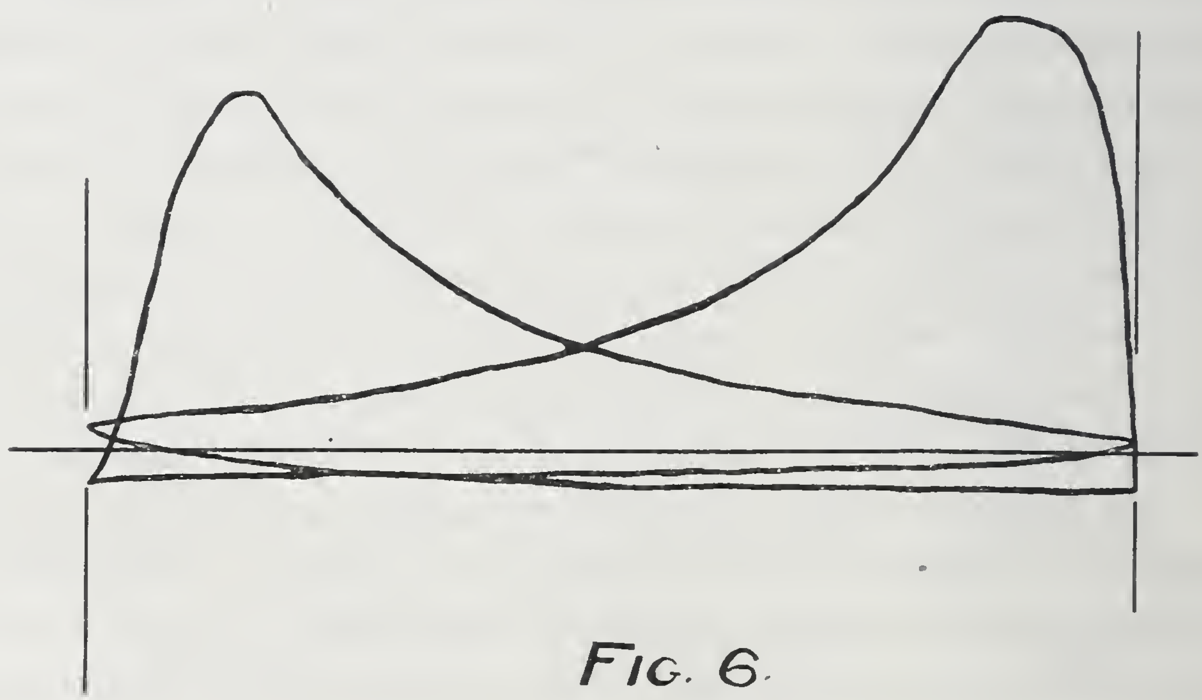


FIG. 6.

The indicator should be used in making the valve adjustments only by an experienced man of good judgment. The conditions exsisting must be studied, and adjustments made accordingly, and not as directed by some cast iron rule derived from a hand book. It is largely a matter of good judgment. The indicator used on blowing engines by inexperienced men has caused more actual damage to the engines, and brought the little instrument into more ill repute among practical men, than is ever conjectured. The impositions on owners of machinery by such incompetent men are simply criminal.

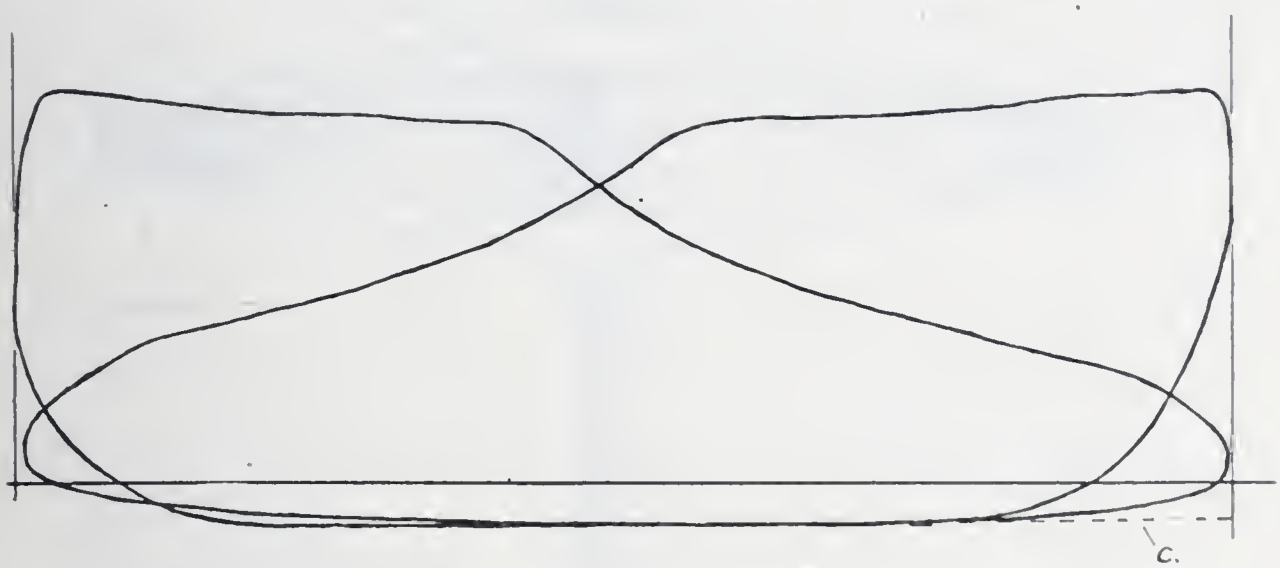


FIG. 7.

To show the actual fallacies exsisting regarding valve adjustment more clearly, a number of diagrams are given, selected from different engines indicated under the supervision of the writer. The diagrams of Fig. 7 were taken from a blast furnace blowing engine, but more nearly illustrate the conditions of a large mill engine. In order to appreciate fully the evil effects of compression on blowing engines—especially those with the long crosshead, having each end attached to a connecting rod, and the piston rods connected in the middle—refer to Fig. 8, showing the pistons at the upper end of the stroke, and then lot us investigate the conditions existing at that point as shown by the diagrams. Consider first the conditions, if there were no compression, and the line of condenser pressure

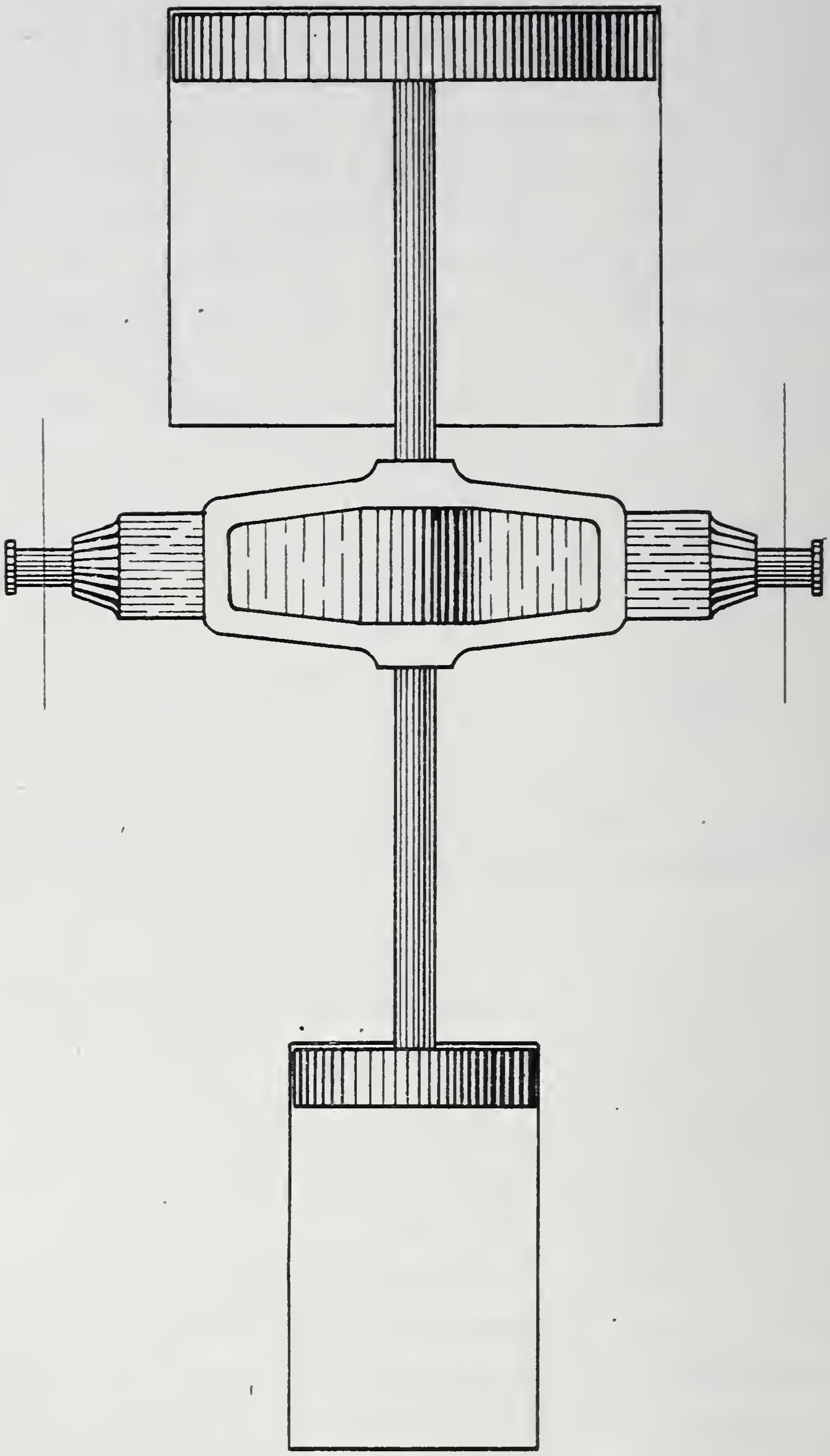


FIG. 8.

produced straight out to the end of the stroke as shown by the dotted line *C* Fig. 7. The unbalanced pressure acting on the steam piston is equivalent to an upward force of 11,250 lbs. The unbalanced pressure on the air piston is equivalent to a downward force of 71,786 lbs., leaving an unbalanced downward force of 60,536 lbs. acting on the middle of the crosshead. Now consider the diagrams as they are with the compression shown. The unbalanced pressure on the steam piston is equal to a downward force of 43,775 lbs., which added to the above force due to air pressure gives a total downward force of 104,310 lbs. acting on the middle of the crosshead. In other words the compression shown which does no good whatever and is not needed, increases the load suddenly applied to the crosshead, over 72%.

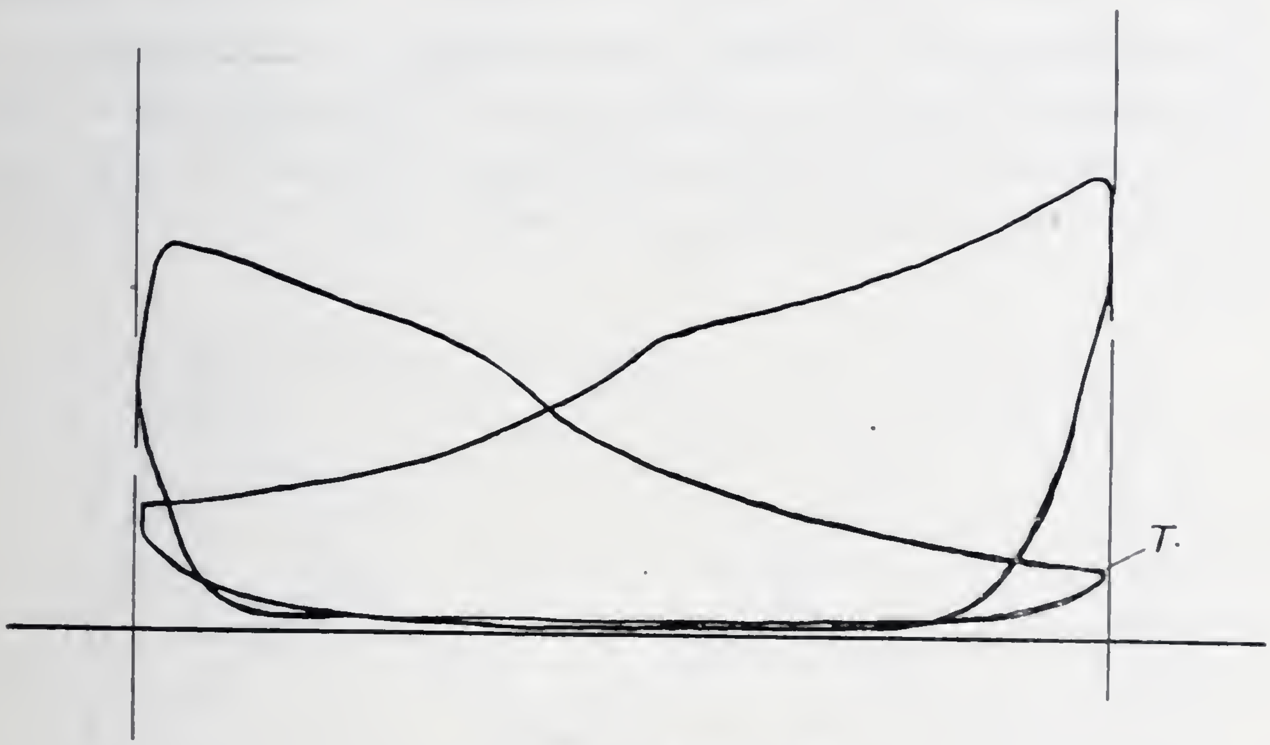


FIG. 9.

A still more forcible illustration of this pernicious practice is shown by the diagrams of Fig. 9. Again let us take the pistons at the upper end of the stroke as shown by Fig. 8. On the upper end of the air piston is an air pressure of 25 lbs. per sq. in., producing a total downward force of 57,255 lbs. Assuming there were no compression in the steam cylinder

there would be a back pressure on top of the steam piston of 2.5 lbs. per sq. in. acting downward. Underneath the steam piston at point T on the diagram is a terminal pressure of 10 lbs. per sq. in. This gives a net force acting upward of 9,425 lbs. leaving an unbalanced force in the center of the crosshead acting downward of 47,830 lbs.

Now consider the actual conditions as shown by the diagram. All other conditions will remain as before except there will be an additional downward force due to compressed steam equal to 44 lbs. per sq. in. on a 40″ piston or a total of 55,290 lbs. This force due to compressed steam plus the above force due to compressed air is equal to 103,120 lbs. acting downward in the middle of the crosshead. This more than doubles the moments of the forces, due to the rods at the ends of the crosshead, tending to break it. The only reason the crosshead did not break, was because one did break and the next one was made "fool proof." The engine has run for months without any compression and runs more easily and smoothly than when strained at each center by compressed steam.

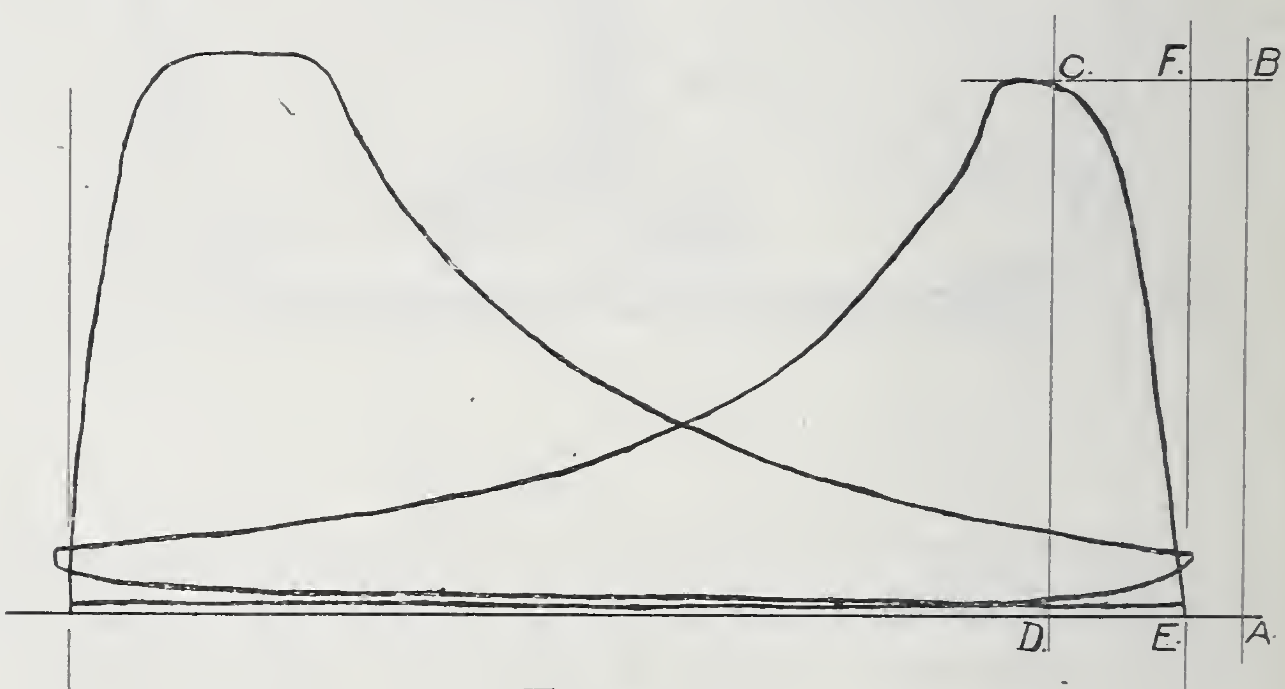


FIG. 10.

Fig. 10 Shows an adjustment considered necessary on a new engine in order to make it pass the centers smoothly. This

adjustment was sanctioned by the superintendent of a large engine manufacturing campany, but it was argued by the writer that if such adnormal conditions were required to make the engine run properly there was something radically wrong with the design. To understand the effect of this diagram let us take a point *C* in the steam line. When the piston has arrived at this point the total volume of steam in the cylinder—assuming 5% clearance, is indicated by the rectangle *A B C D* while the actual work done is only equal to area *C D E*. The possible work is equal to *C D E F*. Area *C D E* is 72% of area *C D E F* showing a loss of 28% in work up to that point in the stroke.

A blowing engine runs very steadily, and when any waste, however small, does exist, its aggregate amounts to a considerable item in a year.

The setting was subsequently changed to admit properly, and no appreciable difference was ever noticed in the running of the engine, proving this adjustment absolutely unnecessary.

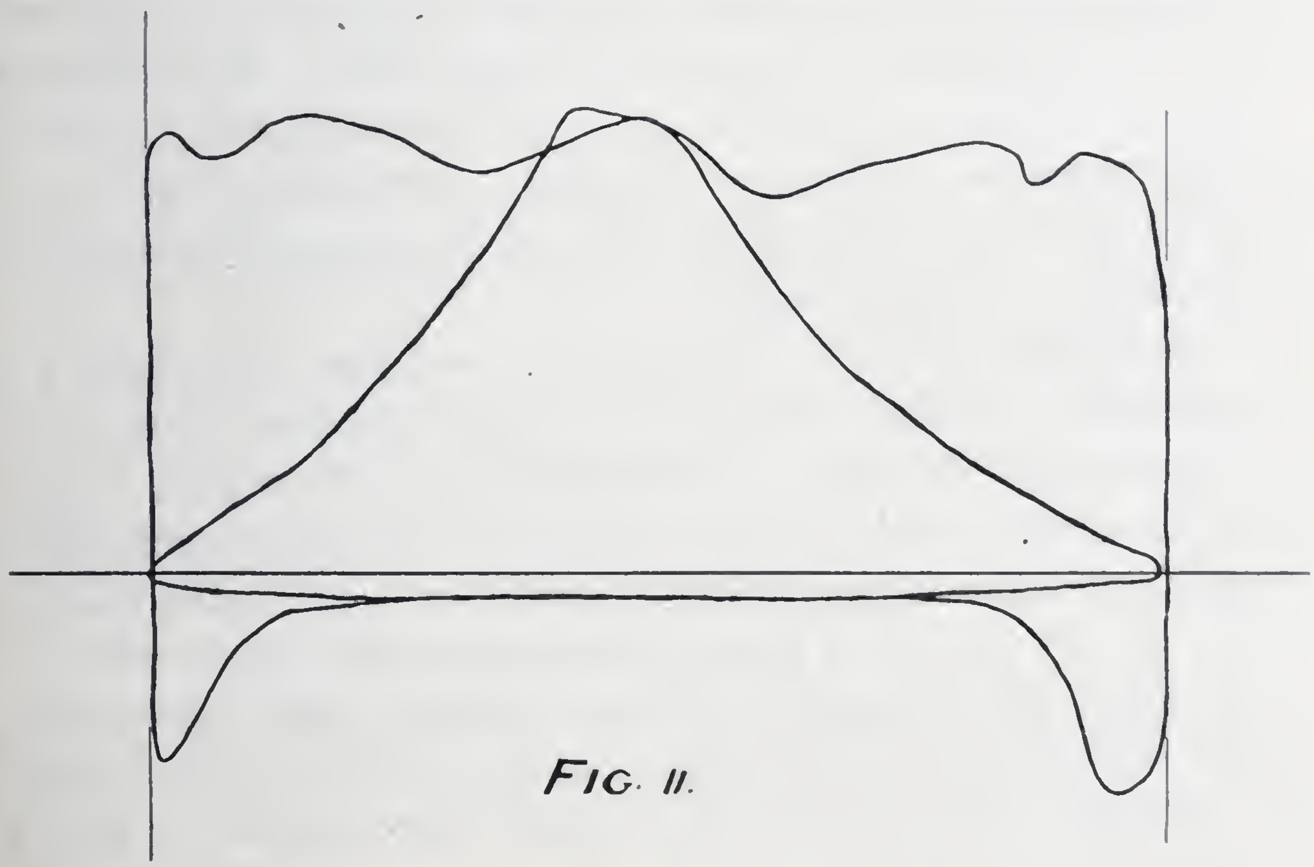


FIG. 11.

Fig. 11 Shows diagrams taken from an air cylinder, and

is given to show the adjustment of the admission valves. The immense vacuum was caused by the valves opening too late, but this was considered necessary in order to make the valves open easily. The facts, however, were as follows: The valves were circular about 20″ in diameter and opened outward from the cylinder moving in a cage. This vacuum in the cylinder, running as high as $7\frac{1}{2}$ lbs. per sq. in., caused the atmospheric pressure to force the packing rings of the valves against the bridges of the ports so tightly at the beginning of the stroke that the seats were worn away in one spot and the valve would leak in a short time. In addition to this it vastly increased the unnecessary work to be done as shown by the proportion of the diagram below the atmosphere line.

The adjustment was determined by a man who had had some experience with admission valves of the gridiron type, which are held firmly to their seats by the air pressure within the cylinder. In this case a slight vacuum in the cylinder, at the beginning of the stroke, is an advantage as it raises the valve off the seat and allows it to open easily. He reasoned that the medicine good in one case should be good in all cases, with the above results. This simply emphasizes the point made before, that knowledge and good judgement are necessary in making such adjustments.

Examples could be continued by the score, but these are considered sufficient to illustrate the most common errors. In every instance the valves were adjusted properly and the engine ran for months, better, and certainly more economically, than before; thus proving conclusively that abnormal conditions are not required to make a properly designed engine run well.

Such conditions and even worse exist at many plants, and will continue to exist, so long as owners of machinery persist in deluding themselves with the idea that because a man is a good veterinary surgeon he ought to be able to play the cornet, or in other words, because a man is a good practical mechanic

it does not necessarily follow that he should be entrusted with the decision of matters which would require the technically trained intellect of an engineer to comprehend.

It is undoubtedly true, that if conditions were such that indicator diagrams could be taken from every engine about once per hour, some of these mysterious and costly breakdowns which so completely wreck blowing engines, could be explained in a very clear and logical manner.

Modern Practice.

The improvements and increase in size of the blast furnace has had its re-active effect on the blowing engine. The larger furnace with its greater burden and the modern methods of smelting, demand blast of higher pressure than was formally used. The blast of the earlier furnaces ranged from 2 to 5 lbs. in pressure, but now 12, 15, 20 and even 25 pounds is blown. The use of large stoves, gas washers, and of the furnace gases under the boilers, etc., compels a higher pressure in order to overcome the resistances and maintain the pressure in the system.

The development of water tube boilers has made higher steam pressure practicable, 120 to 150 lbs. now being quite common. This renders the use of compound engines desirable, and of course these are made condensing. In some plants the ordinary simple blowing engines are connected to condensers, and in others, two simple engines are compounded—where the construction is such as to permit it—and then connected to the condenser. The tendency in many of the modern plants being to more and more rigid economy in the use of heat. Of course there are plants in which this not true, and they seem to be content to move along fifteen years behind the times in their methods, and will continue to do so until throttled by competition.

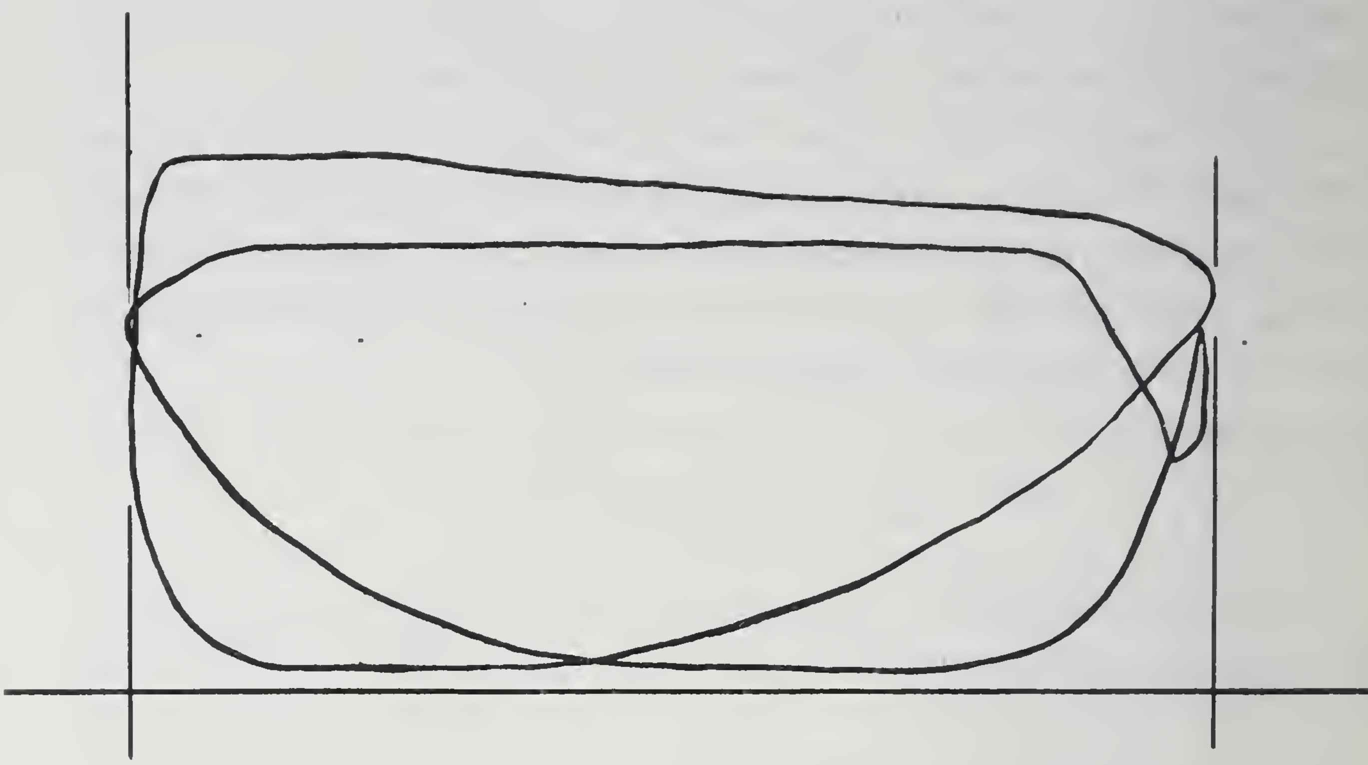


FIG. 12.

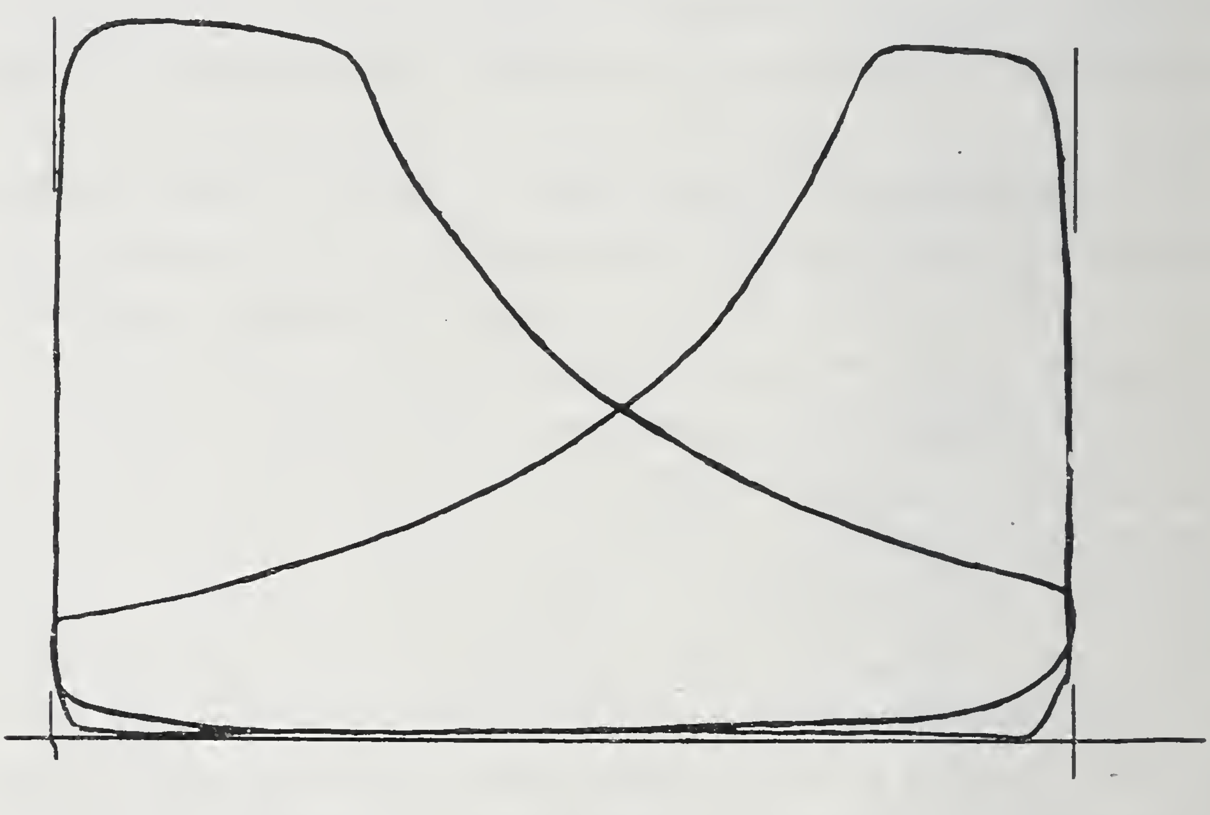


FIG. 13.

Probably nothing could illustrate this tendency toward economy better than the three sets of indicator diagrams shown by Figs. 12, 13 and 14. These were all taken from the steam end of the same engine, but at different times. The diagrams of Fig. 12 show the original condition of the engine struggling to do its work under conditions that are simply frightful. Of

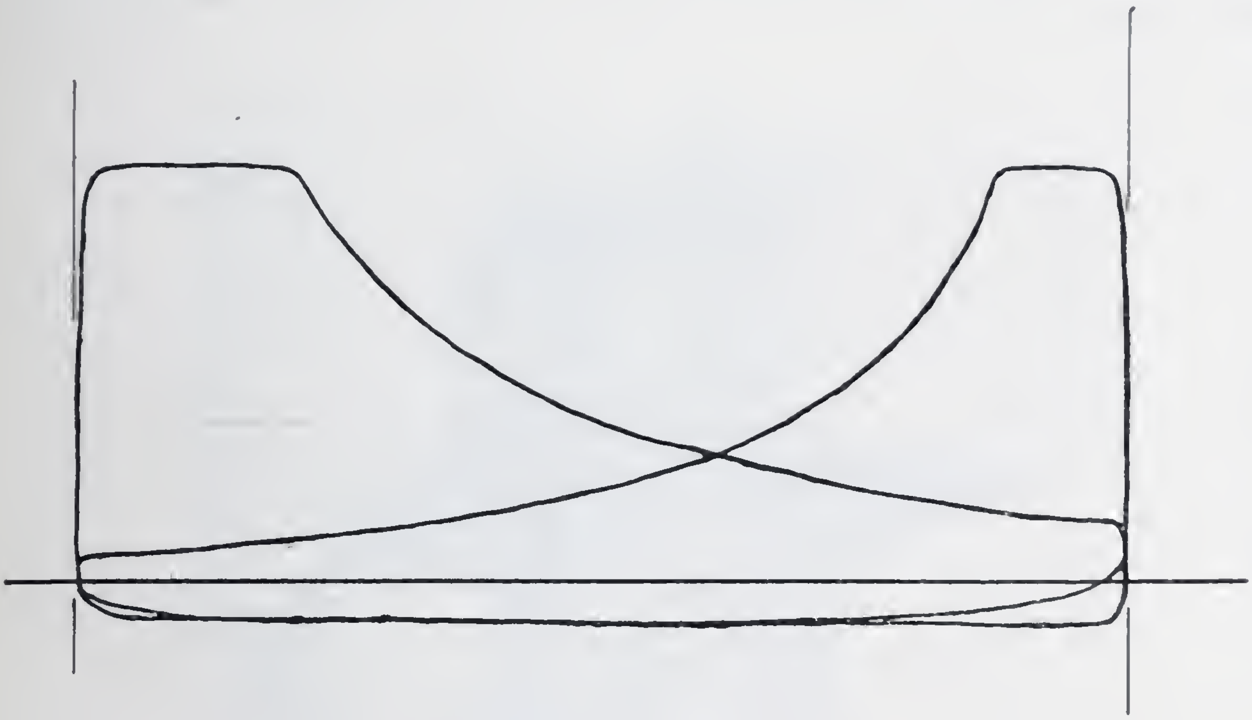
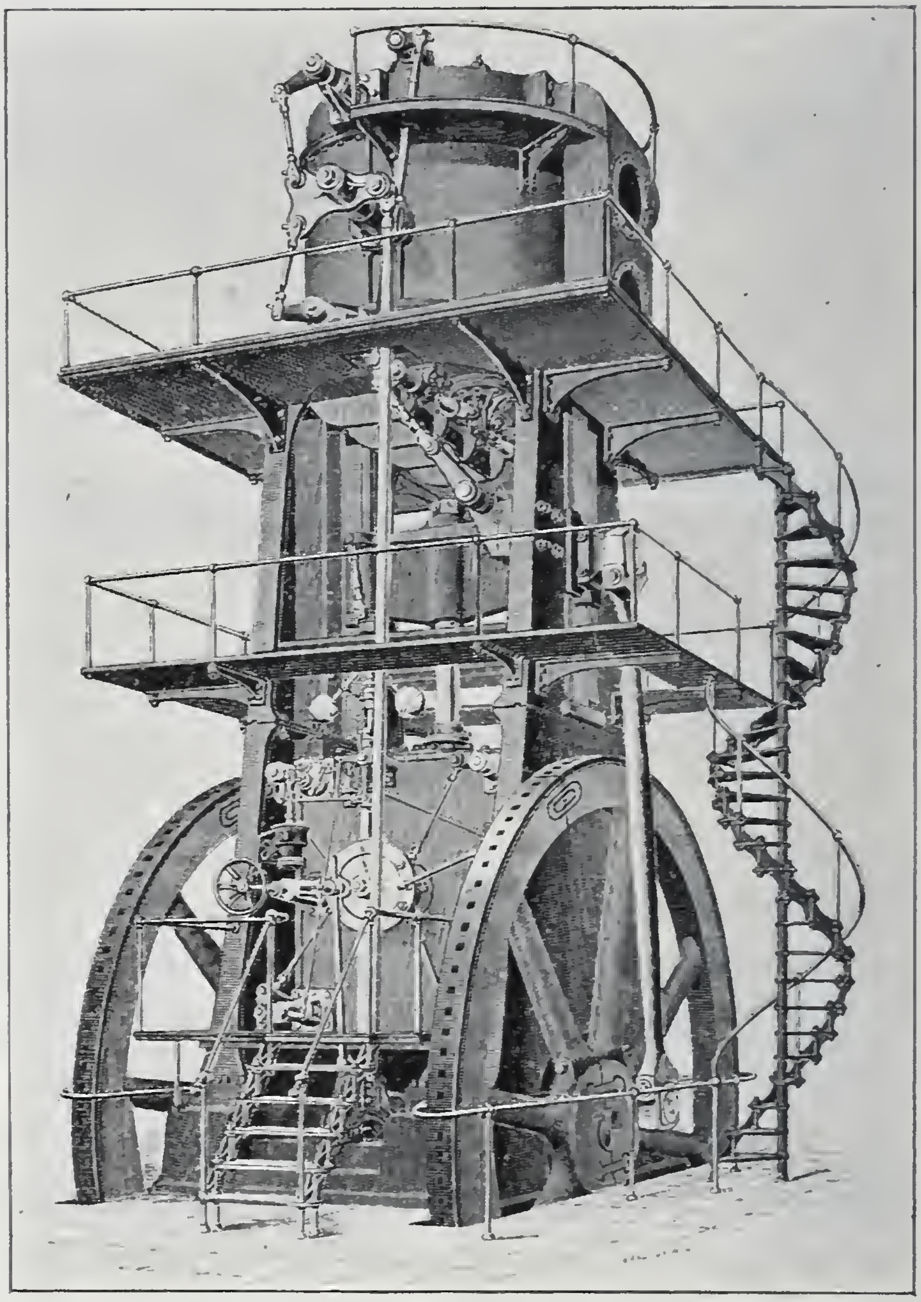


FIG. 14.

course between the diagrams of Fig. 12 and those of Fig. 13, a change of cylinder was made, the Corliss valves being adopted. Diagrams of Fig. 14 show the same engine made condensing. The writer estimates that if this engine be assumed to run but five days out of the six, the saving in boiler power alone effected annually by the difference in the conditions as shown by Fig. 14, over those of Fig. 12, assuming same power in first case as in latter, would be worth over $4,000. Such changes are not alone good engineering but good business policy.

The blowing engine now in most general use in this country is the simple vertical engine with the air cylinder directly over the steam cylinder. A detailed description of this engine is hardly necessary, as the illustration given will serve to make the general arrangement very plain. One of the weakest points of this design is the long crosshead. This was discussed fully in considering the effect of compression in the steam cylinder, and need not be considered here. The mechanical efficiency of this type of engine is very high.



Simple Vertical Blowing Engine. Common Type.
E. P. Allis Co.

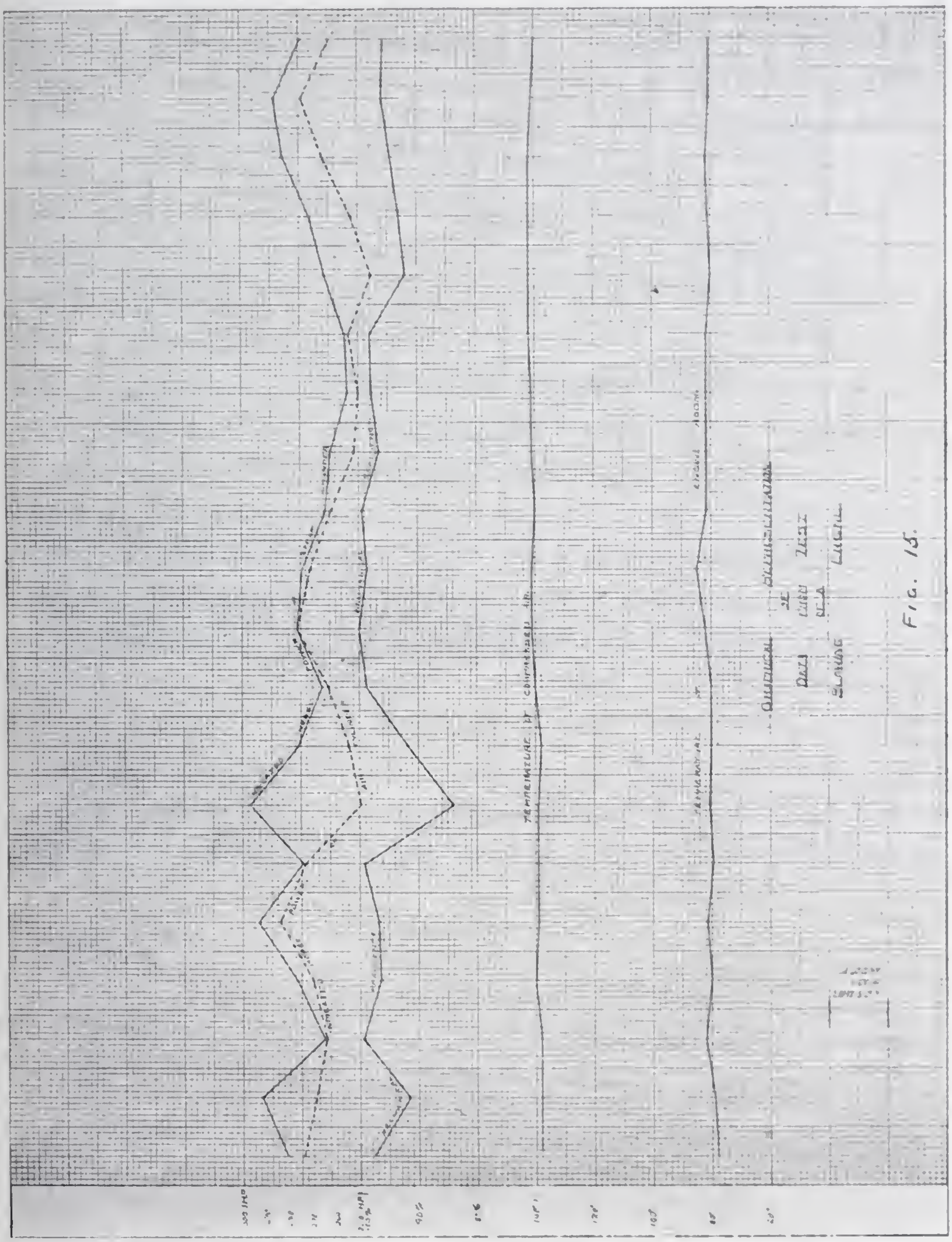


Fig. 15-A.

The engine being vertical and a large proportion of the power transmitted directly from one cylinder to the other, renders the friction very slight. In a number of tests of this type of engine, which the writer has made the mechanical efficiency varied from 95% to 98%. The set of curves shown by Fig. 15-A illustrate very clearly the data taken during one of these tests. All observations were made and cards taken simultaneously every ten minutes. The conditions remained very constant, as will be seen from the curves which are drawn to a rather large scale in order to make the variations conspicuous.

Another type of engine which is coming very rapidly into popular favor is shown on pages 223, 224, 225 and 226. This is a vertical cross compound with the air cylinders above and in tandem with the steam cylinders. These engines are certainly very fine machines, and their popularity is evidenced by the fact that one manufacturer alone has built thirty-eight for different iron works within a comparatively short time. Their ponderous proportions are in perfect harmony with the huge modern furnaces, while their valve mechanism is conducive to the best economy. Figs. 15, 16 and 17 show diagrams taken by the writer from an engine of this type. These show nothing exceptional but simply the ordinary conditions of regular

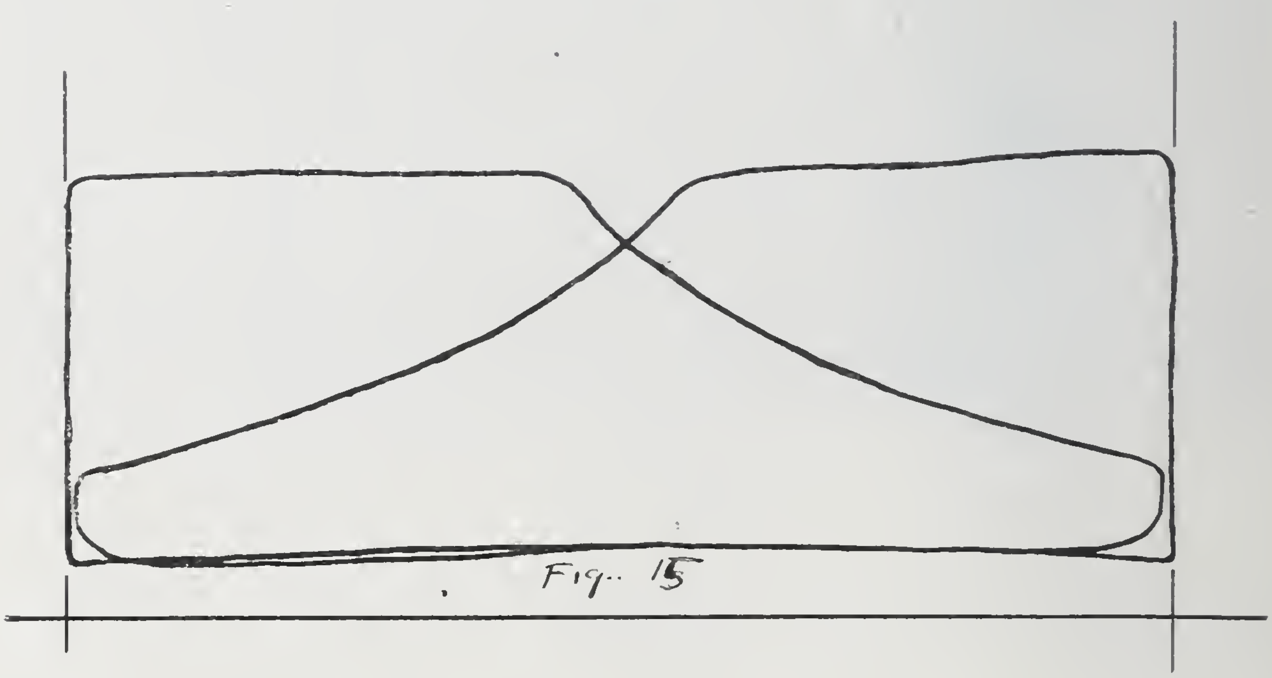


Fig. 15

service. Anyone familiar with blowing engine practice will not fail to appreciate the conditions existing.

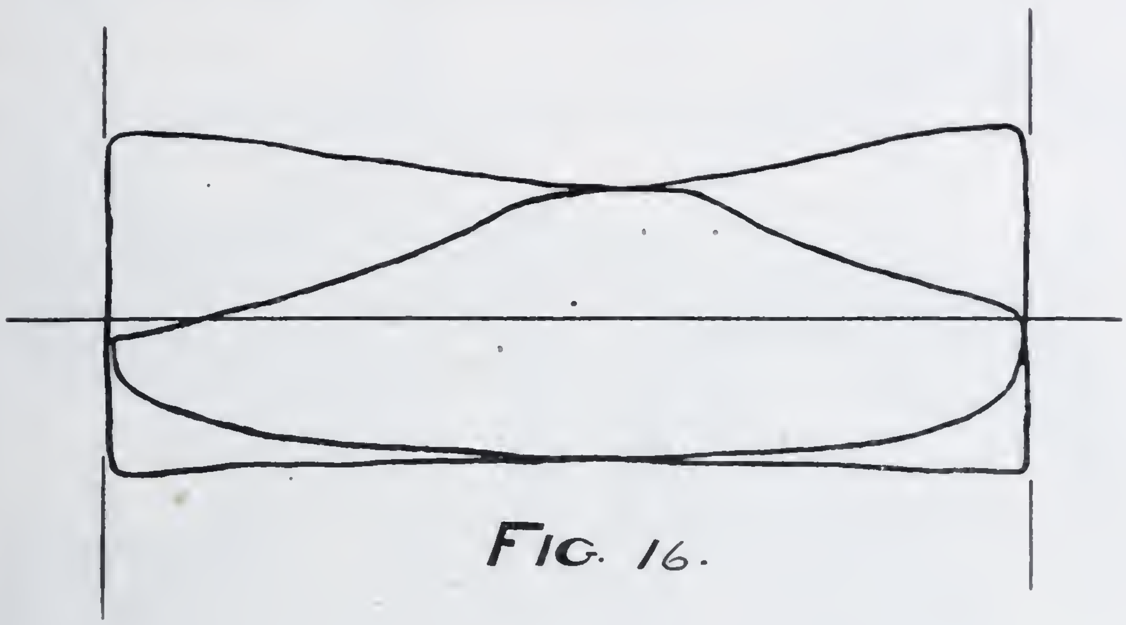


FIG. 16.

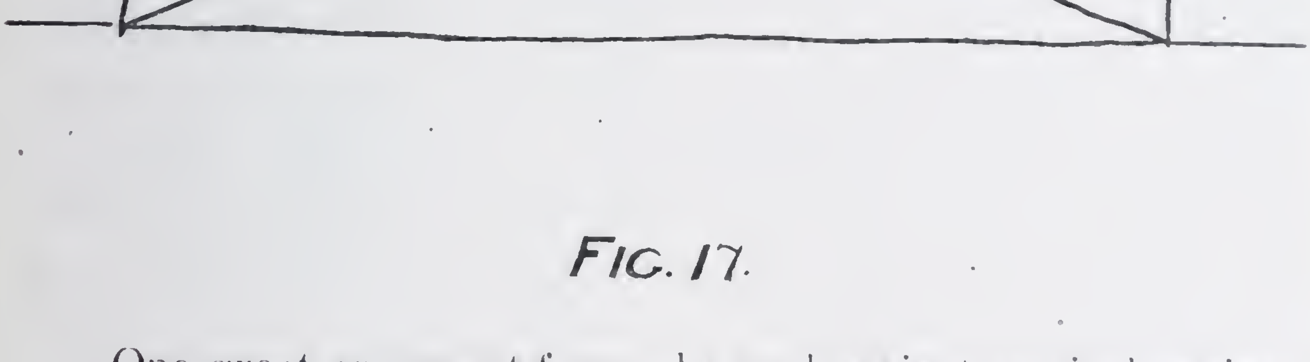
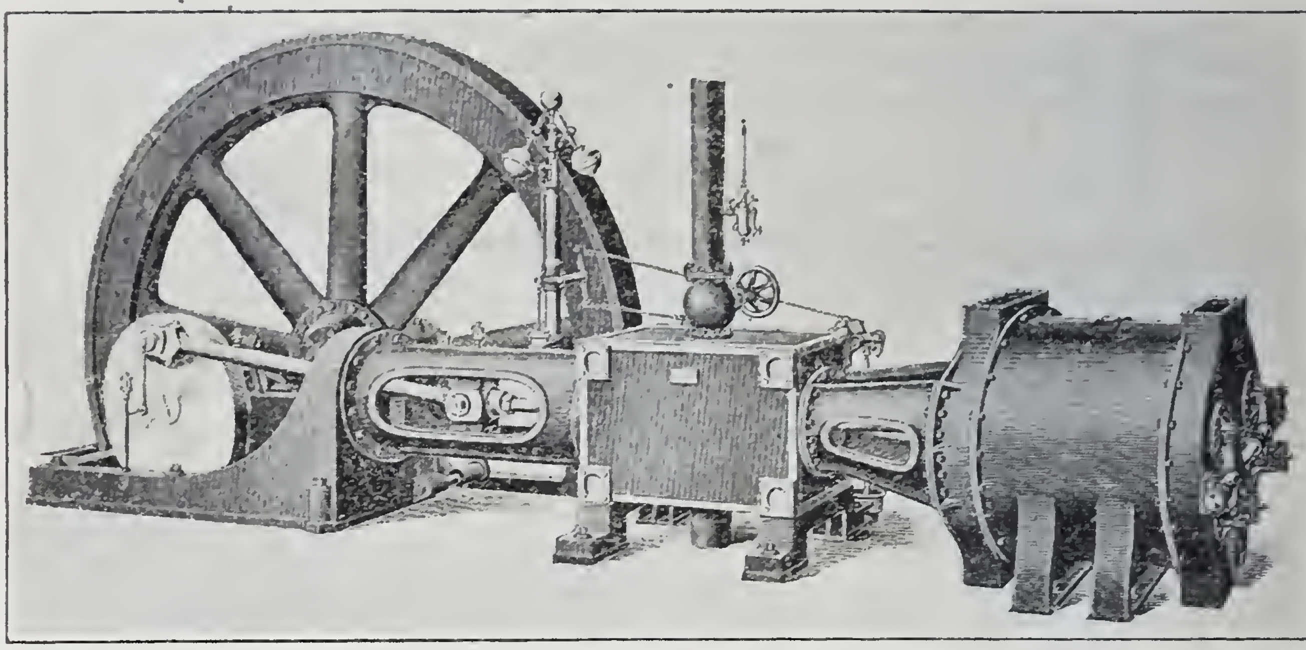


FIG. 17.

One great argument formerly used against vertical engines was "too much vibration." The writer has been on top of these engines over 40 ft. from the floor level while they were making 45 R. P. M., and found the vibration very slight indeed.

Another advantage of this type of engine is that it renders the use of the long crosshead unnecessary, thus obviating a very fruitful source of break-downs.

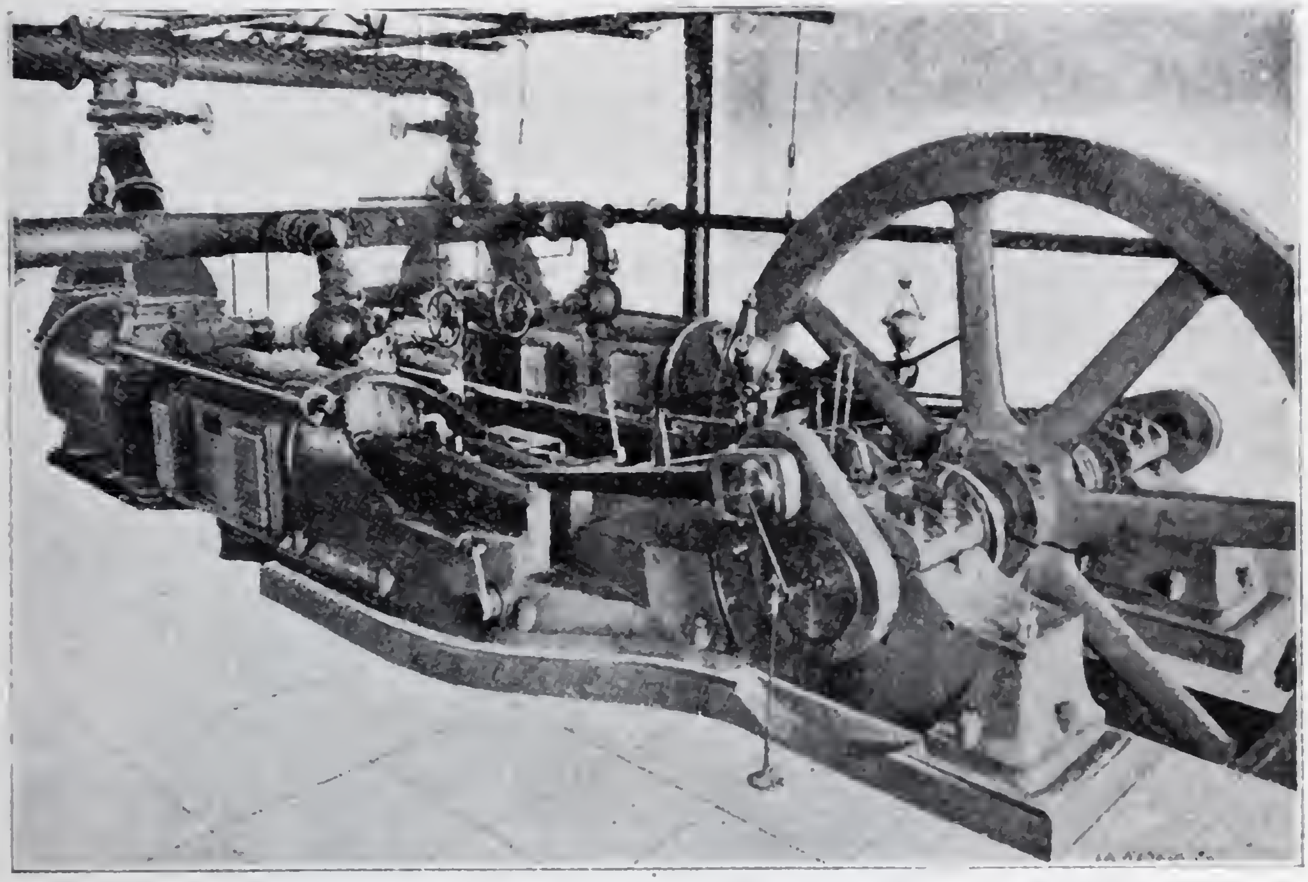
The great disadvantage of all vertical engines is especially emphasized in this type. That is their inaccessibility—the great inconvenience of working on them in case of repairs or break-downs. The parts being so large and so high above the floor renders repairing an exceedingly difficult task.



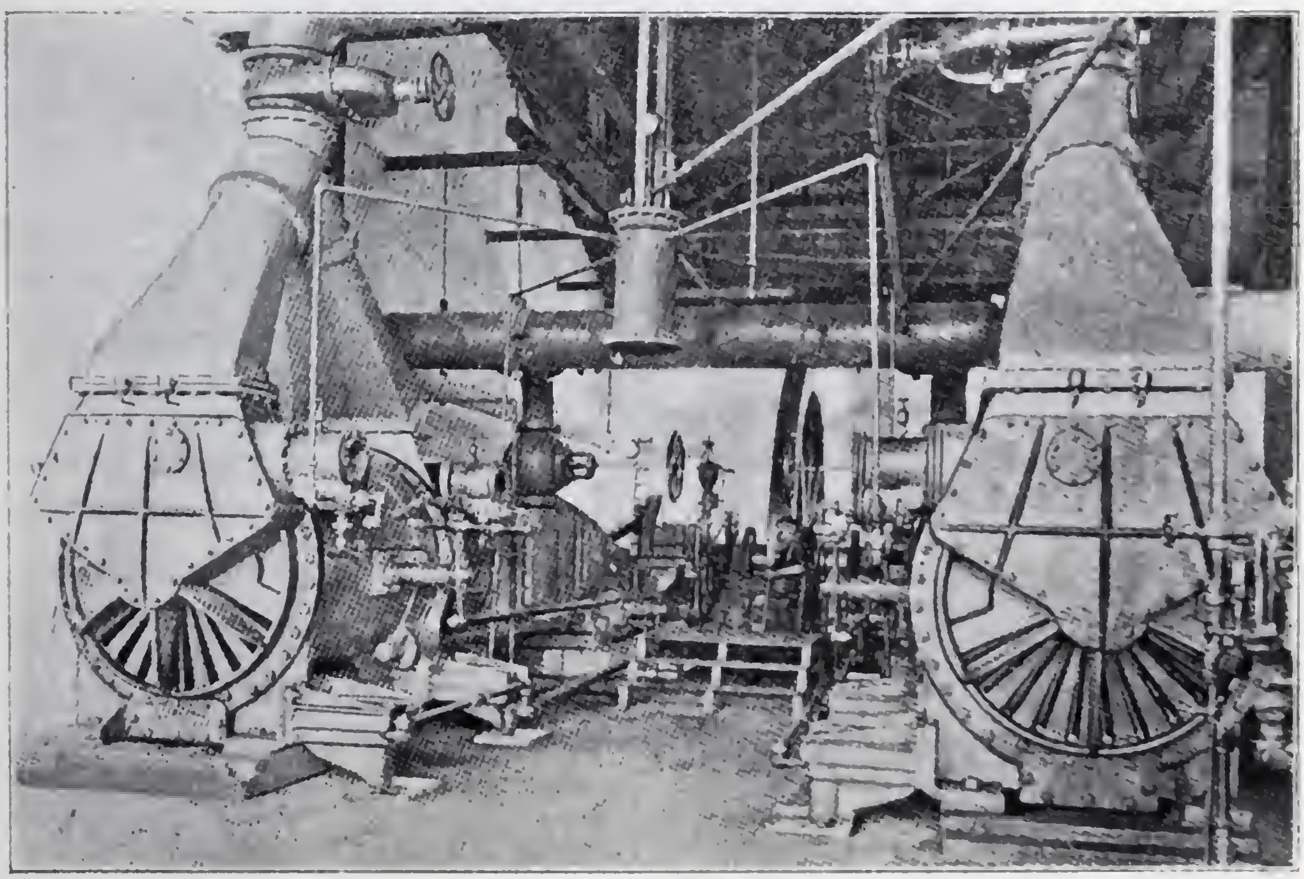
E. P. Allis Co.—Horizontal Single Blowing Engine.

Horizontal blowing engines are also used to some extent, but their use is not nearly so general as that of the vertical type. The principal reason for this is the amount of floor space which they occupy. They are certainly much more convenient and accessible than the vertical type, and where sufficient space was at all available, these reasons would seem to justify their use. Anyone need only work over the two types for a time to appreciate the convenience of the horizontal engines.

Corliss steam valves are now very generally used on all types of blowing engines. The conditions of service are especially favorable to their use. Metal air valves moved so far as possible by positive mechanical means are displacing leather, rubber, and other short lived materials moved by air pressure. Cast iron packing rings are used in the air cylinder instead of wood, and of course cylinder oil must displace the graphite as



Southwark Automatic Twin Bessemer Blowing Engine.—Side View.



Southwark Automatic Twin Bessemer Blowing Engine.—End View.

a lubricant. Metallic packing is used on the rods instead of soft packing.

This discussion indicates in a general way the trend of the best modern practice. During the past ten years all lines of engineering have moved forward with tremendous strides, but it seems the blowing engine has kept abreast of the blast furnace.

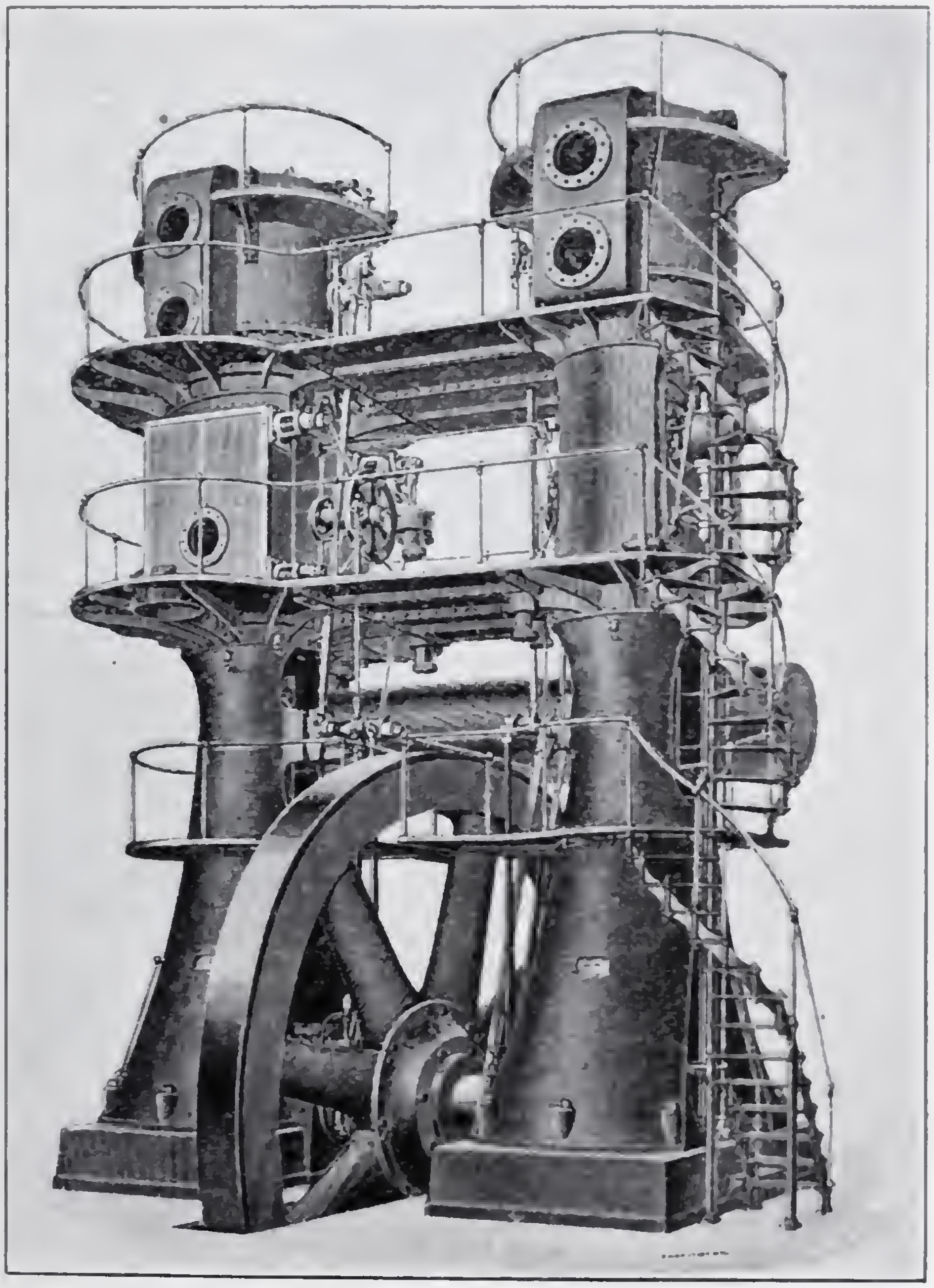
Future Probabilities.

What the future has in store for the blowing engine builder it would be foolhardy to predict. In the face of the stupendous achievements of modern engineering we dare not even conjecture.

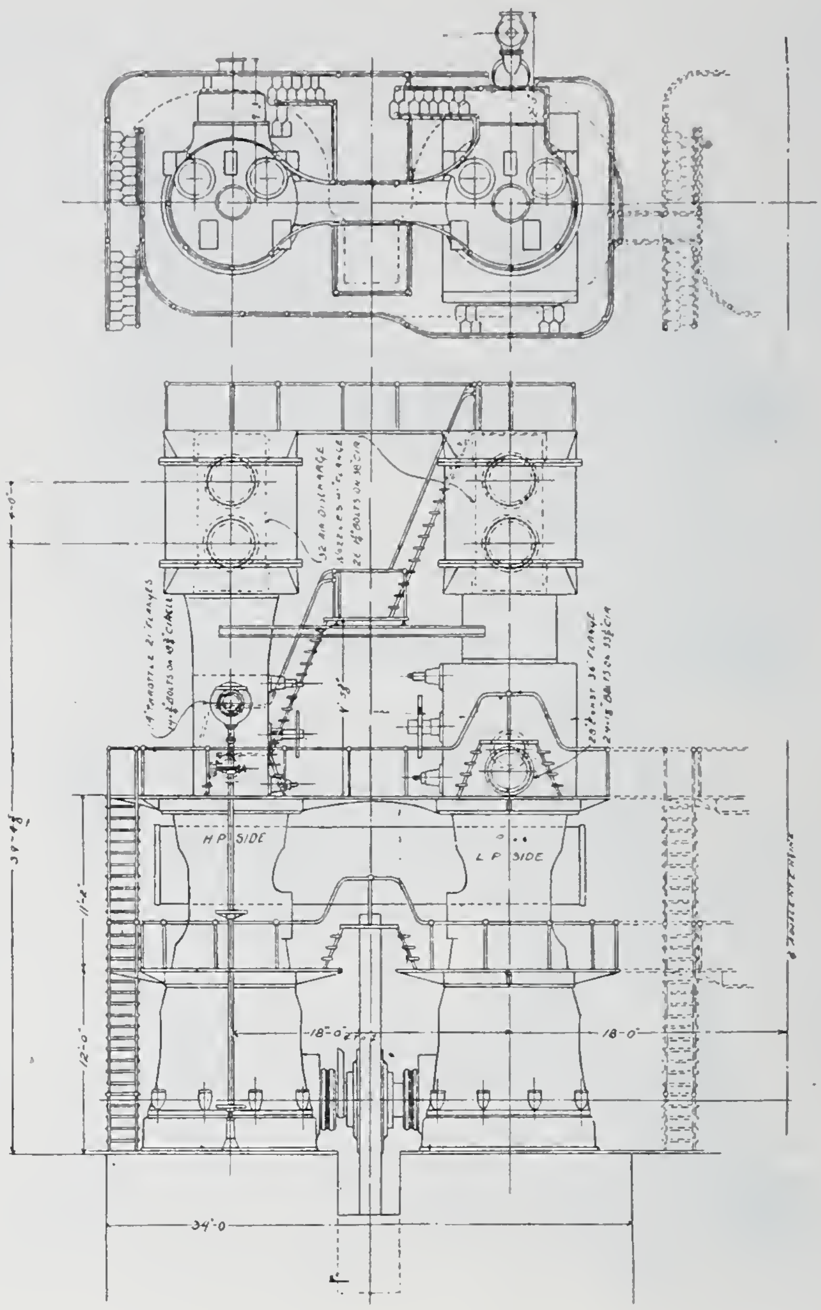
We can say, however, with some degree of certainty that liquid air will not intrude itself in this domain for some time to come, however broad its fancied field may be.

Still higher steam pressure and triple expansion engines would be legitimate successors, in the line of evolution, to the present encumbents.

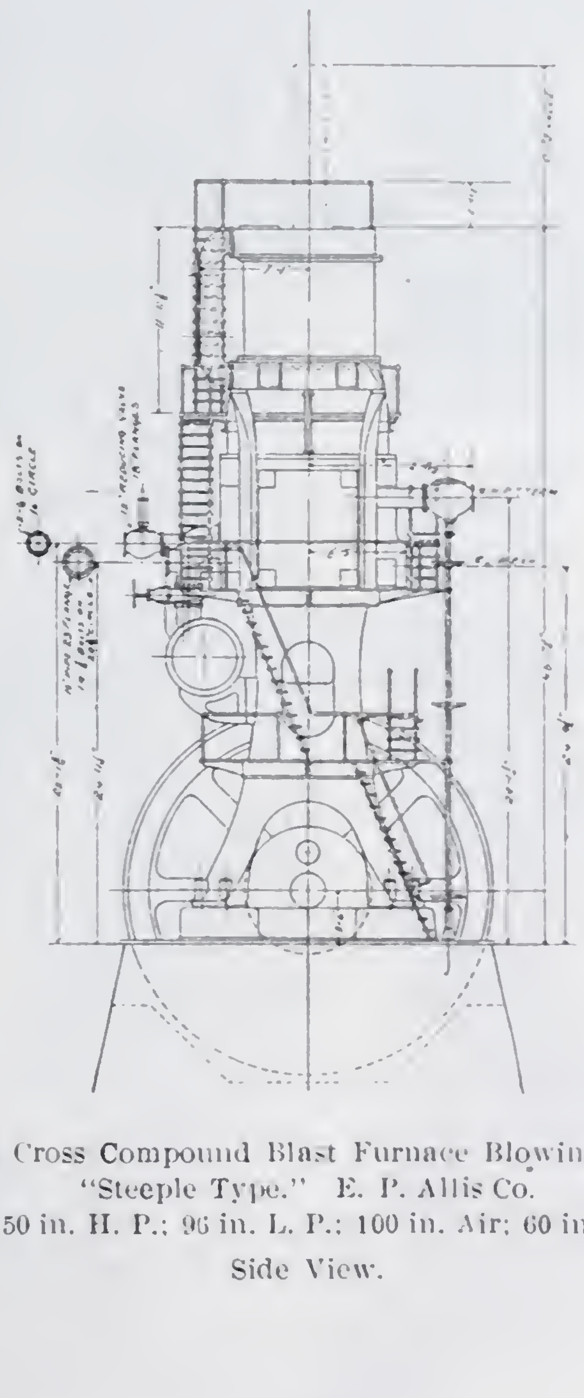
The combustion of the waste gases of the blast furnace directly in the cylinder of a large gas engine seems to offer the greatest inducement for investigation. This method of driving blowing engines may be said to be in its experimental stage now in Europe and many very satisfactory trials are reported. However, it may be with this as it has been in the past under similar circumstances. When the keen mind of the technical scientist of the continent, delving deep into the fields of knowledge, upturns a seed the fruit of which he knows not, the sun of American ingenuity must shine upon it, the rains of American capital must fall upon it and cause it to germinate and spring up when the light of American enterprise will ripen it, so that the fruit may be plucked and enjoyed by all the nations of the earth.



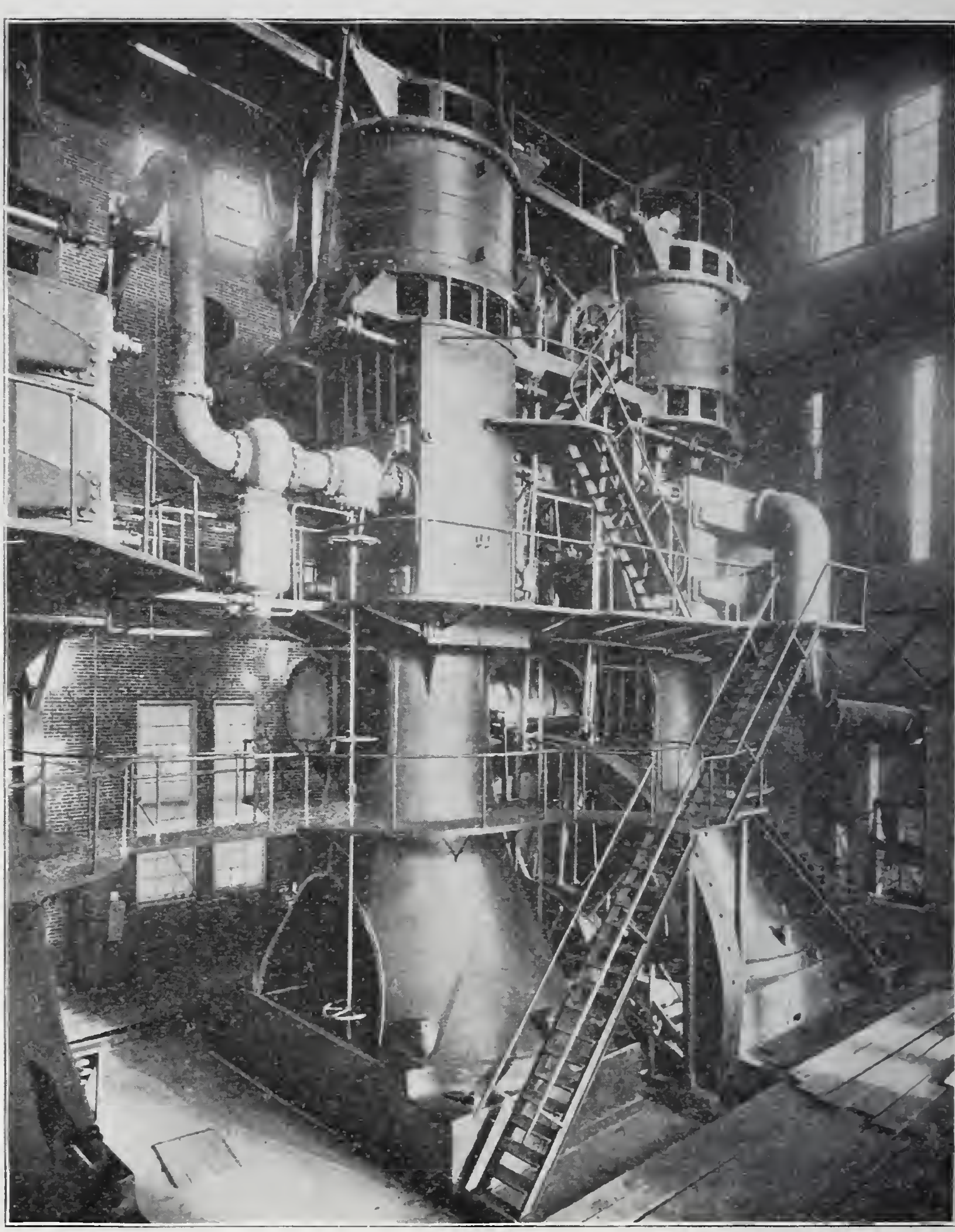
E. P. Allis Co.—Vertical Cross Compound Blowing Engine.
Modern Type.



Vertical Cross Compound Blast Furnace Blowing Engine.
"Steeple Type." E. P. Allis Co.
Size, 50 in. H. P.; 96 in. L. P.; 100 in. Air; 60 in. Stroke.
Front View.



Vertical Cross Compound Blast Furnace Blowing Engine.
"Steeple Type." E. P. Allis Co.
Size, 50 in. H. P.; 96 in. L. P.; 100 in. Air; 60 in. Stroke.
Side View.



Vertical Cross Compound Steeple Type Blowing Engine.
One of three, built by William Tod Co.

Dr. R. G. G. Moldenke—In looking over these diagrams the peculiar value of an indicated engine is seen. I have indicated a great number of engines myself and I find the conditions as shown in some of these cards exhibited to be similar to my own. Every engine in my charge is indicated regularly. Some engines are run in this city for years without any attempt, so far as indication is concerned. In one case I know of, it was never suspected that the governor was broken until the card showed it.

Mr. Bole—It is comparatively few engines that ever have an indicator applied after they are sent out into service. An engine may run over a term of years and use steam worth twenty or thirty times its value, and still have the reputation of being a good runner. I think every one who has taken part in this kind of work will stand by the indicator.

A Member—Perhaps Blowing Engines could be driven with blast furnace gas?

Mr. Snyder—I could not say much about that. I have never seen it tried practically in this country, and I only know what I have read. I know of quite a number of interesting and successful trials of that way of using it. There is one just reported in the current issue of *Power* which is one of the best tests they have as yet made. There may come a time when the use of furnace gas in this way will become common, but it seems to me the one trouble in using it in gas engines, with the ores now used, would be the large amount of dust in the gas.

Dr. Phillips—I recently had a letter from a friend who has been abroad looking into that question. Speaking of the dust he said he had seen a case where they had been just using a gas engine without the dust collector for six months and it was in good order. He was astonished to see it. In another case a Society authorized the statement that they had used a gas engine four months and the dust did not interfere with them at all.

Aside from the question of the efficiency is the fact of the increase of size in the furnace. In the old days we hear that 3, 4, or 5 pounds was considered sufficient. Now furnaces come up to 22 to 25 pounds. Some furnaces will be doing well on one class of pig iron, and if they make a different kind of pig iron they will have to go up to 16 or 17 pounds. I know of a case some years ago where they had been running at 9 or 10 pounds and they made a failure. With the same stock they ran the pressure up to 15 pounds and had good results. I would like to ask Mr. Snyder if he considers nitrogen, etc., dilatorious?

Mr. Snyder—I regard it in this way. If we use oxygen very successfully for smaller combustions I hardly understand why we could not control it if we could use it on a large scale. I do not mean that oxygen would be blown into a furnace by a 60x84 in. blowing engine at 20 lb. pressure, but all conditions would be proportionately modified. However, I simply brought that in as of general interest rather than of any special importance.

Mr. Bole—As far as concerns the use of gas blowing engines I can contribute this much. Engines as large as 800 to 900 indicated horse-power have been used in Belgium very successfully. The problem of getting rid of dust and ash has been handled by passing the gases through streams of water to wash and separate them. Some of the engines have been built vertically, the piston acting upward so the dust would be deposited on the cylinder head and blown out. There seems to be no difficulty in the use of such gas. At the present time there is great interest in this country on that line of thought. Our own company has within a very few days started up an engine which we are using as an experiment purely. This engine which is 225 horse-power uses blast furnace gas and is expected to generate electric currents for use at the mill. That matter is becming very seriously agitated. From the stand-

point of fuel economy it is a very pleasing proposition. There seems to be a good deal of prospect in it.

I would like to know what effect high blowing pressure has on the quality of pig iron. We are buying high priced iron in one section of the country while in other sections we get a cheaper grade very near equal in chemical contents.

DR. R. G. G. MOLDENKE—If you take two irons of exactly the same condition, subject them to tests, you will see. In some furnaces there is an oxidation of iron while it is made. A chemical test alone is not sufficient. It requires the chemical test and the physical test combined to show that the iron is right. The chemical analysis may be all right but the iron wrong. It is my practice to take a car load on trial and have it as low in silicon as convenient. It is usually the low silicon iron which shows up an iron best. I make my mixture in such a way that I can get the maximum amount of that iron into it and then watch results.

MR. BOLE—If iron is burned in the furnace what will be the effect on the iron?

DR. MOLDENKE—The result will be that the iron is weak. The crystals will not stick together and it seems that there is a coat of oxide of iron formed between them. Some time ago I placed one sample of steel after another in a furnace that was being gradually heated up to 2400°F and took them out of the furnace in different heated conditions. Placed under a microscope you could see the grain of the crystals change, getting coarser and coarser as the temperature had been higher. There was of course oxide of iron observed in the steels of the highest temperature ranges. This was an experiment which took me from eleven o'clock Sunday night until two o'clock in the morning and opened up a new light entirely upon the effect of oxygen on steel at high temperatures. Charcoal iron is better than coke only because it is produced at a lower blast temperature.

MR. BOLE—Where you know of the presence of oxygen in the burning iron what is the manifestation?

Dr. Moldenke—It gets hard.

Mr. Bole—Not so much by the presence of gas bubbles as by hard spots and blotches?

Dr. Moldenke—That is generally the way it shows its presence. To determine properly when you have a good pig iron, get your chemical composition correct and make a transverse test to see that you have the proper strength. Then run your cupola mixture right and I know the result will be satisfactory.

Mr. Albree—I just want to remark in connection with that paper that when I called on Mr. Snyder a short time ago he told me he did not have any ready. I told him that he had been with the Schoenberger people a good many years and knew that line of work perfectly and that he surely could give us something of interest at this meeting, and you have seen the result. Now there are a number of members of this Society who could give us something very interesting on their particular line of work, if we could just get them to do it.

Mr. Bole—I think it was Socrates who made the remark that any one is sufficiently eloquent on any subject with which he is perfecly familiar.

Mr. Flint—I would like to say that some users of blast furnace gas claim that they do not clean their gases. They claim they cool their gases before they turn them into the blast furnace engines or that the cooling process is a process of washing them with water, so that they do clean them perhaps as effectively as some people who use an apparatus for that purpose.

A vote of thanks was tendered Mr. Snyder by the Society for his excellent paper.

On motion the Society adjourned at 10.30.

Reginald A. Fessenden,
Secretary.

SEPTEMBER 20, 1900.

The regular monthly meeting of the chemical section was held at 410 Penn avenue, Mr. Handy in the chair.

Minutes of the June meeting read and approved.

There being no new business a paper by Mr. F. H. Williams on "The Influence of Copper in Retarding Corrosion of Soft Steel and Wrought Iron," was read by the Secretary.

INFLUENCE OF COPPER IN RETARDING CORROSION OF SOFT STEEL AND WROUGHT IRON.

F. H. WILLIAMS, Wheeling, W. Va.

The deterioration of iron and steel from rusting is so important a matter, that every effort to discover a means of arresting or retarding this otherwise ultimately fatal disease ought to be encouraged, and any results attained should receive consideration.

During the late spring of this year, the writer made some tests on the corrosion of iron and steel on a small scale. They were made especially to find what influence the presence of copper might have, and are in line with recent investigations by Mr. H. M. Howe, as given in his paper "Relative Corrosion of Wrought Iron, Soft Steel and Nickel Steel," read before the International Congress on Testing Materials.

Four samples of steel were selected, viz., A, an ordinary soft Bessemer steel; B. C. and D., soft Bessemer steels to which copper had been added, so that they contained respectively 0.078%, 0.145%, and 0.263% copper. In addition to these another set of tests, consisting of one soft Bessemer sample and four wrought iron samples were similarly treated. It will be noticed that wrought iron sample No. 4 contained 0.393% copper.

Small pieces of each were cut and filed to same dimensions, weighed and suspended on a frame so that all could be dipped simultaneously in water and left to hang in the air till

dry. This treatment was repeated frequently each day for about a month. The daily increase in weight due to oxidation was small but of such a persistent character as to apparently indicate the retarding influence of copper upon the corrosion. Finally, when there appeared a tendency of the oxide to scale off, the treatment was concluded, and the pieces were thoroughly cleaned of all oxide, and weighed. The loss in weight appears in per cent. of the original weight of pieces, in the following tabulated form:

LOSS FROM ATMOSPHERIC CORROSION.	LOSS %
A.—Soft Bessemer Steel	1.85
B— " " " with .078 copper	0.89
C— " " " " .145 "	0.75
D— " " " " .263 "	0.74

STEEL AND WROUGHT IRON.	LOSS %
Soft Bessemer Steel	1.65
Wrought Iron, Sample 1	0.76
" " " 2	0 80
" " " 3	0.87
" " " 4......(containing .393% copper)	0.53

The investigation of Mr. Howe upon large plates of metal extending over considerable time, show that nickel exerts a similar retarding influence upon corrosion.

The introduction of a small amount of copper into steel, where it is not already present in sufficient quantity, could easily be effected through the use of copper-bearing iron ore in the blast furnace.

Its presence in steel within the amount necessary for obtaining the above results, has been shown by others to be not prejudicial to its physical qualities or to its mechanical production. It would seem as though the facts here presented might help to solve the problem of making soft Bessemer steel as capable of resisting corrosion as wrought iron, and thus end the debate as to whether the one or the other is the more rapidly corroded.

The work was approved, and the hope expressed that the experiments be continued.

Prof. F. C. Phillips gave a brief account of the papers read at the summer meeting of the American Chemical Society in New York. Other subjects of interest that were discussed were Gas Analysis, Gas Producers, Molytdeum Steel and Aluminum Steel.

If the interest and profit attending these meetings were better understood more chemists would participate.

Section adjourned at 10 P. M.

GEO. O. LOEFFLER,
Secretary C. S.

Engineers' Society of Western Pennsylvania.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The one-hundred and eighth regular meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture Room of the Society's House, 410 Penn Ave., Pittsburg, Pa., Tuesday evening, October 16, 1900, thirty-five members and visitors being present. The meeting was called to order at 8.40 o'clock, by the President, Mr. W. A. Bole.

The minutes of the previous meeting were read and approved.

For the Board of Directors, the following applicants were reported as passed, and to be voted for at the next regular meeting.

A. O. BACKERT, - - -	Manager, Of the Pittsburg Branch of the Iron Trade Review, 429 Park Building; House, 430 Arabella St., Knoxville, Pa.
JOHN H. CARLIN, - - -	Machine Dealer, Carlin Machine & Supply Co., Allegheny, Pa; House, 435 Graham St., Pittsburg, Pa.
MARTIN J. DOWLING, - -	Superintendent, Bessemer and Open Hearth Dept. of Jones & Laughlins Co., Ltd., Ward and Cato Sts., Pittsburg, Pa.
CHARLES VAN CUE WHEELER,	Superintendent, Projectile Dept. Firth-Stirling Steel Co., Demmler, Pa. House, 1014 Ridge Ave., Allegheny, Pa.,

The following gentlemen were balloted for and duly elected to membership.

W. H. H. GINDER, - - -	Chemist, For American Sheet Steel Co., Vandergrift, Pa.
EDWARD HOERLE, - -	Superintendent of Construction, Duquesne Steel Works and Blas Furnaces, Duquesne, Pa.; House 5649 Second Ave., Pittsburg, Pa.
FRANK C. NEWELL, - -	Electrical Engineer, For Westinghouse Air Brake Co., Wilmerding, Pa.; House, 423 Ross Ave., Wilmerding, Pa.

REPORT OF COMMITTEE ON THE DEATH OF COL. WM. A. HERRON.

In the death of Col. Wm. A. Herron, the Society of Engineers of Western Pennsylvania is called upon to mourn the loss of its oldest member. He was born in this city August 7th, 1821, and at the time of his death, on May 6th of the present year, was nearly eighty years old.

Col. Herron was one of the earliest graduates of the Western University of Pennsylvania. While still a young man he was engaged with his father, John Herron, in the coal business; supplying the local trade including several of Pittsburg's infantile iron works, from mines located in that part of the present city known as the 13th Ward, in proximity to the Herron Hill reservoir, where his father owned a considerable quantity of land. In 1846 he engaged in the coal trade more extensively, shipping by the way of the Ohio in floating boats, to Cairo, from whence the coal was towed by steamers of the Mississippi river to St. Louis, where it was used for gas making. About the period of 1855 he was engaged in the banking business, and was among the promoters of the German, now the German National Bank, the Iron City Trust

Co., which subsequently became the Second National bank, and was also one of the organizers of the People's Savings Bank. From about 1860 to 1866 he was Clerk of the County Courts, and during the year last mentioned entered the real estate business in which he was actively engaged up to the time of his death. He was for many years a director in the West Penn Hospital, a member of the Executive Committee of the Dixmont Insane Asylum; vice-President of the Homeopathic Hospital; Director of the Young Men's Home, and an active member of the Young Men's Christian Association, also President at the time of his death of the Western Pennsylvania Institute for the Blind. In all of these charitable and philanthropic associations he took an active and vigorous part. He was also a member of the Chamber of Commerce, the Civic Club, and a few other organizations looking towards the public welfare, and it was through his individual efforts that the Pittsburg chapter of the Sons of the American Revolution was chartered. Since 1890 and until his death, Col. Herron was the agent for the Schenley estate in this city. He was among the early promoters of the horse car lines on the streets of Pittsburg. His brother, Richard G. Herron, who died in 1893, a civil engineer by profession, was for a number of years manager of the Center Ave. line to Herron Hill. Col. Herron is survived by his wife, two sons and one daughter, the sons retaining the active management of the large business which their father created.

It has been the lot of but few of the business men of Pittsburg to live to the age attained by Col. Herron, and few indeed in the long history of the city have enjoyed to the same extent as he did, the esteem of their fellow citizens. His was indeed a model life, retaining to the end that kindly and sympathetic, yet dignified frankness of manner so characteristic of gentlemen of the past generation.

The Engineers' Society of Western Pennsylvania is proud to have had enrolled in its membership the name of William

Anderson Herron, and desires to express to the members of his family, its sympathy in their great loss.

THOMAS P. ROBERTS,
W. L. SCAIFE.

Mr. Hyde for the Reception Committee stated that unfortunately he had been absent from the last meeting, but that the matter of the smoker should receive prompt attention.

The Chair announced the death of Jas. L. Rankin, Jr., and appointed the following committee to prepare a suitable memorial resolution: Messrs. Edwin Yawger, Julian Kennedy and F. Z. Schellenberg.

The next in order was the reading of the paper of the evening by Gerald E. Flanagan, entitled, "Notes on Traveling Cranes."

NOTES ON TRAVELING CRANES.

BY GERALD E. FLANAGAN.

In presenting, to a society of engineers, a brief paper dealing with the general subject of traveling cranes, it is extremely unlikely that anything new will be developed, and I must disclaim, at the outset, any intention of speaking technically to designers of such machines. But, since all engineers must, from the nature of their daily occupation, be interested more or less directly in the purchase and operation of these useful tools, a general consideration of the subject may not be out of place; even though nothing more be done than to recall to mind features and problems which have been already weighed and considered, and questions be raised rather than answered.

From a time centuries previous to the building of Egypt's pyramids, unceasingly through the lapse of years to the present day, the problem of lifting and transporting large masses has been a vital one, and a principal factor in our material progress; until to-day there is, perhaps, no one feature of our industrial conditions of such vast importance to the welfare of the race as the question of transportation in its various forms.

The day of the supremacy of mere brute strength in our mills and factories ended with the substitution of the locomotive for the pack-horse on our roads, and all our methods now tend to the reduction to a minimum of the need for the exertion of physical strength; and instead we harness the energies that emanated from the sun during centuries long gone by. There are various methods by which these energies, buried for so many thousand years in the coal beds, may be made to serve as our lifters and carriers; and accordingly we have had many types of cranes, both rotary and traveling, operated severally by steam, water, compressed air, belt, shaft and rope transmis-

sions; all useful and practicable methods, and modern ingenuity might be depended upon to produce far greater results with any of them than has yet been done if there were no better means at hand. The development of the electric motor, however, has rendered all the other forms of cranes more or less obsolete for general shop service, although there are many special requirements for which the older forms are most admirably adapted. One has but to compare the appearance of the old-time shop, with its numerous swinging cranes and various makeshift methods of handling heavy weights, themselves presenting no small obstruction to the progress of work on the floor, with that of its more recent prototype under the influence of one or more modern, high-speed electric travelers. In the latter case, the floor is left clear for the operations of various legitimate functions thereon, while masses of material are carried bodily over other work in process of erection. In fact, overhead cranes capable of carrying a one hundred ton locomotive are not uncommon, while the directness with which they accomplish their work is apparent when we consider that, in the hands of a skillful operator, the combined motions of the bridge and trolly, which are usually carried on simultaneously, result in approximately a straight line in the desired direction. For the sake of saving time the hoist motion is, not infrequently, caused to act along with the other movements of the crane. All of these operations are rendered more directly feasible by the ready adaptation of power derived from electric motors, and, so far as one may at present predict the future, the electric crane bids fair to hold ground far in advance of its rivals for general service. Power cranes driven by rotating square shafts may perhaps be regarded as the immediate forerunner of the electric traveler, but with their manifold objections, not the least of which were the tumbling bearings for supporting the driving shaft, they were promptly abandoned when something better presented itself. In the earliest applications of electric power, the effort was made to have one motor

furnish power for several different motions, involving clutches, frictions, and other objectionable features. Even with independent motors, the old-time crane with its high speed bi-polar machines and multitudinous small gears presented an appearance vastly different from the crane of to-day, with its few parts, and simple strong construction.

Recent requirements in some large shops have called for the installation of a large number of cranes upon the same runway, often of greatly varying capacities, and the employment of what have been sometimes called "double deckers" is steadily growing in favor. The term "double decker" is certainly a misnomer in this connection, as it simply refers to two indedendent cranes, one placed high enough to pass over the other, and, if anything be "double decked," it is the building. Usually the upper crane is much the lighter of the two, though sometimes the reverse is the case, in order to attain the requisite height for handling large pieces, and also for the heavier and larger sheaves and longer hook required, but this involves carrying the heavier supporting columns to the greater height and correspondingly increasing their sectional area and consequently their cost. The lower crane is a shorter span, to allow it to clear the supporting columns of the upper one. Sometimes, if comparatively light, the runway for it is carried on brackets from these columns. Where two cranes are not desirable, the same end may be in some measure attained by designing the heavy slow speed trolley with the addition of a light, quick acting auxiliary hoist, for the rapid handling of small loads, or by using two trolleys on the same bridge.

Similar to the ordinary traveler is the gantry crane, with runway on the ground level. In this form, the end truck comprises a structure, usually in the form of a capital A, or, for the sake of making simpler connections, sometimes bearing a greater resemblance to capital H, and of a height sufficient to give the required elevation to the trolley. Either form of structure requires to be well braced laterally, to provide for

strains due to suddenly starting and stopping the crane, which, as the center of gravity of the moving mass of machinery and load is so far above the rails upon which it runs, must always be more or less of an unknown quantity; but, in the nature of things, will at times be very severe.

Traveling cranes are essentially a class of machinery which should be substantially constructed, with all parts amply proportioned for the loads they may be called upon to sustain. Gearing should be of steel, and for smoothness of action and quiet running, cut teeth are much to be preferred. Malleable iron gives fair results, but will not stand the same amount of abuse as steel castings; while cast iron has its low cost chiefly to recommend it. The master gears, that is the wheel directly connected to the drum together with its pinion, usually have the teeth shrouded to the pitch line, so of course, cannot have cut teeth. The wheel is best connected directly to the drum, to avoid driving through a shaft, and should be of comparatively large diameter to reduce the load upon the teeth. These gears should be arranged as shown in Fig. 1, in order to put the least load on the drum shaft bearings. It will be noticed that, for the proportions given, the pressure is three times as great arranged as in Fig. 2, for the same load on the hoisting chains. This principle should be observed throughout the entire train of gears, but it is one that is frequently lost sight of. Gears should not only be strong enough to endure the load, but should be of ample pitch and broad face to insure wear. Pinions ought to have not less than fifteen teeth, and the line had best be strictly drawn at twelve as a minimum. The so-called thumb-shaped teeth are occasionally used on master gears where greater strength is required with a given pitch. Since simplicity is an admirable quality, the best designs avoid the use of such features as bevel gears, miter gears, internal gears, worm and spiral gears. Idle gears are also an objection, as they waste power in friction, and are productive of nothing unless it be noise. The drum is almost

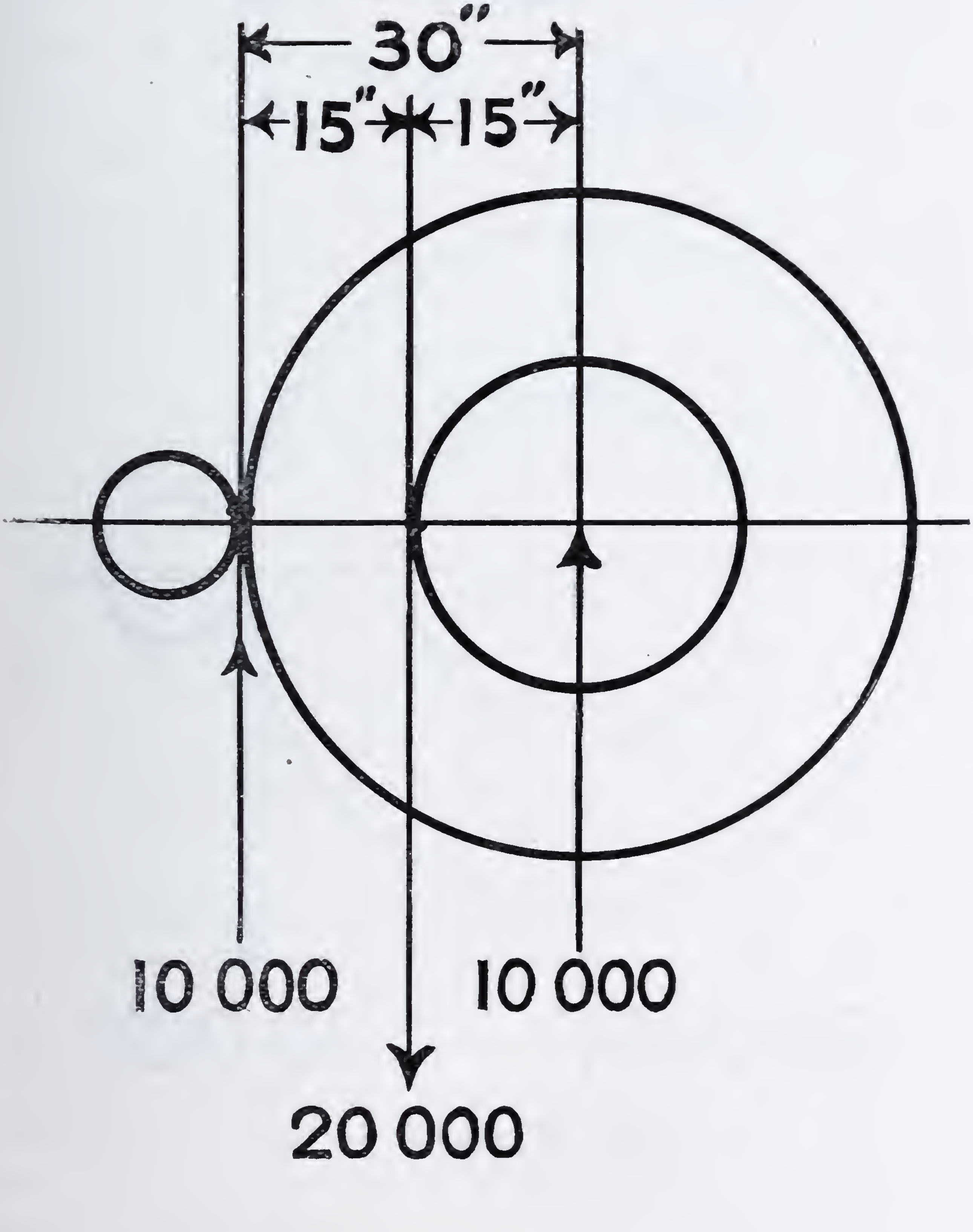


FIG I.

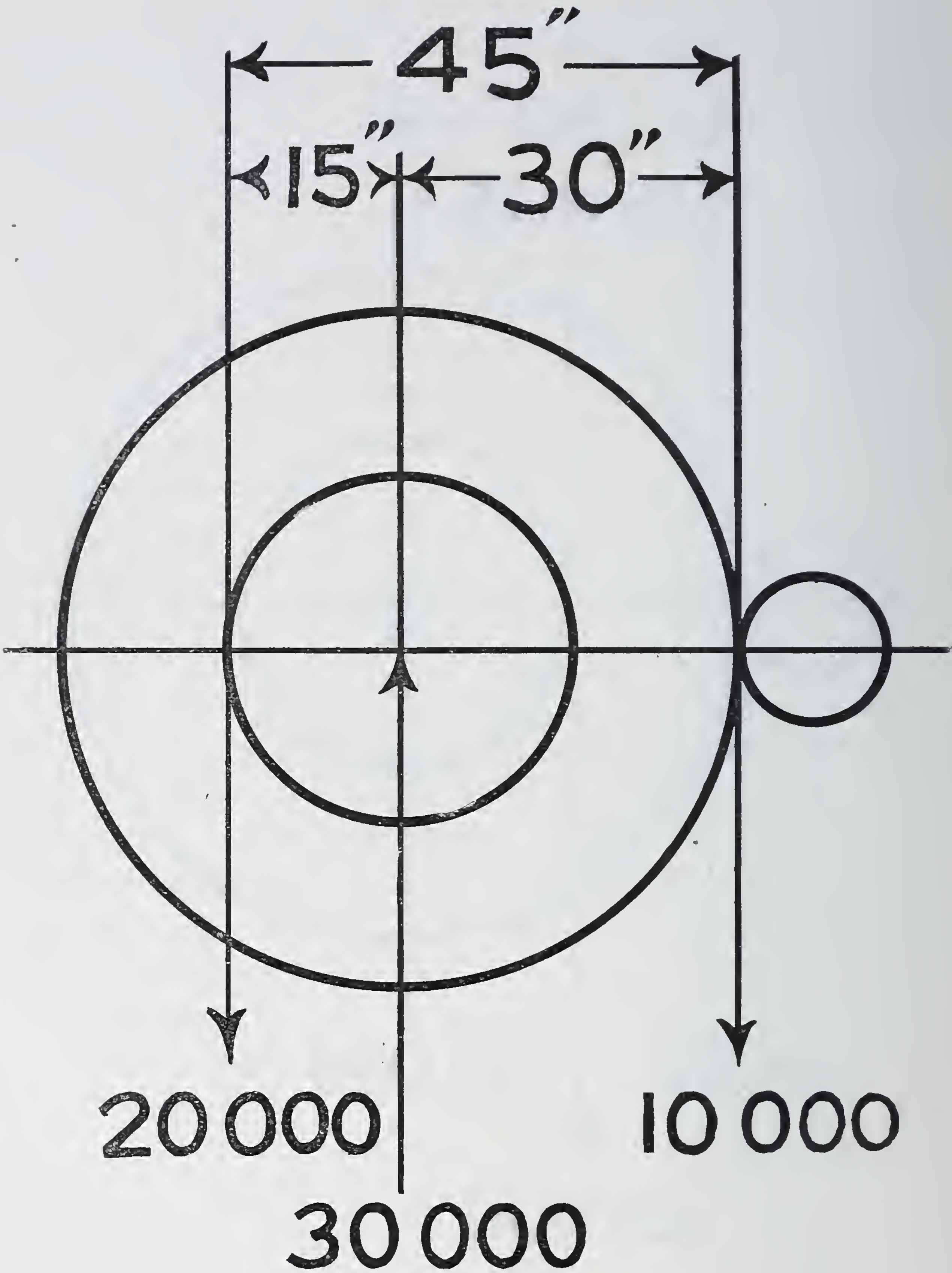


FIG. 2.

invariably of cast iron. The smaller ones are cast solid upon the shaft, while the larger sizes are hollow and keyed in place, but are heavy enough to offer great resistance as a center loaded beam. The outside is turned to a true cylinder, with accurately shaped spiral grooves, rightly spaced to suit size of chain links. In the matter of chains, the best is none too good. Short link, well made special chain of tough homogeneous material is needed, and it should not be required to go around a drum or sheave less than twenty to twenty-five times the diameter of the iron from which the chain is made. The chain should be securely anchored to the drum, and be long enough to leave from one-half to one full coil on the drum, with the hook in its lowest position. On some smaller cranes and hoists, wire rope is used in place of chain, requiring less room. Chain sheaves are usually turned with grooves the same as the drum, and with deep flanges to prevent the chain from working off. Sometimes the groove is omitted and a ridge left in its place, the links then lie across this ridge at an angle of about fifty degrees with the plane of the sheave. This form of wheel meets with less favor than the other style, but takes less room. The lightest cranes have the hook suspended from a single chain, and present the objection that the load sways freely from side to side, if either the trolley or bridge is started suddenly. Where the chain is led from the drum down under a sheave and back to an anchor on the trolley, there is greater steadiness, in one plane at least; and where the chain is fastened at each end of the drum, winding toward the center around a right and a left hand groove, carried beneath double sheaves at the hook, and the center of it hung over a balancing sheave connected to the trolley, we have four point suspension, and a minimum amount of swaying of the load. Still heavier work requires eight chains with additional sheaves, but involves no change in general form. Two drums are used at times, with a view to producing a perfectly vertical lift, but result in a multiplicity

of parts and increased cost. Between the respective merits of light chains and many of them, and heavier chains and fewer of them, opinions differ, but the desire to simplify, limits the number to four, or at most eight, and the fewer times a chain is bent around a sheave the better for it. Hooks are made from forged iron or steel, or from cast steel, and they are a feature that calls for the very best material of whatever kind, while a reasonable degree of liberality as to size is no objection. In this matter experience is a good guide, but if depending upon calculated results, a safety factor of about ten should be used. The traction wheels for both trolley and bridge are best made of steel, or good chilled iron, the latter metal being preferred. They should be of heavy pattern, large diameter, with strong flanges on each side, and run upon broad, flat headed rails. The driving gears are usually keyed direct to the hubs of the traction wheels, which latter are then provided with phosphor bronze bushings, and run upon fixed pins. This construction permits of a very efficient method of oiling through the axis of the pin. The simplest form of axle pin is merely a piece of round steel with a rectangular projection upon each end, fitting into a corresponding slot in a plate bolted to the trolley or bridge trucks, which holds the pin firmly against both rotary and endwise motion, admits of easy removal, and does not interfere with the method of lubrication above mentioned. Other methods of fixing the pins are by means of keys, set screws, bolts tapped into the joint, clamps in the form of caps, or regular capped bearings in which the axle is allowed to turn.

Of first importance in the operation of a crane are the brakes, which are provided to control its various motions. In the smaller ones, the hoist motion only is so cared for, but in more important cases they are applied to the trolley and bridge movements also. A magnetically actuated brake is usually deemed sufficient for the two last mentioned movements, but the hoist should, in addition, be fitted with an automatic me-

chanical friction device to control the speed of lowering, and to assist in holding the load securely at any point. The wheels for the magnetic brakes are generally attached directly to the armature shaft, which may have an extension on one end for this purpose. The simplest ones are, perhaps, the best. A plain cast iron wheel turned smooth on the rim and encircled more or less completely by a steel band lined with wood, leather, or other renewable wearing material. Bronze makes a good but a more expensive wheel, steel has the advantage of being strong and consequently can be made light, a matter of some importance, at times, as the fly-wheel action of a large and heavy brake on a high-speed motor is quite noticeable, and renders the armature that much harder to stop. The wheel rims are either flat or V shaped in section, the latter form giving a somewhat better grip for the same pressure. With this, the wooden blocks are framed to fit the groove. The band should be made adjustable as to length, and when made to go entirely around the wheel is often in two parts, one end of each being connected in a knuckle joint and supported free from the brake wheel ; the other ends connect to the gripping lever operated by the electro magnets. This construction lessens the tendency to stick to the wheel when it is not wanted. Bands which encircle only half the wheel circumference are much used. They should be applied to the lower half of the wheel, and will then fall away from it when released. A point in their design to be noted is that the pull is against the fixed end, otherwise the tendency will be to raise the lever and lessen the pressure. The action of these brakes is as follows: Electro magnets, formed usually of a pair of solenoids, with soft iron plungers, connected through a yoke to the brake lever, raise the band from the wheel when the current is on, and drop it instantly the current is cut off, the brake applying itself by the force of gravity. Magnets may be shunt or series wound, but must be designed to lift with the least current which will operate the motor, since, if a large current be applied for the

purpose of releasing the brake, the motor will start too suddenly. They must also be capable of carrying the maximum motor current, if series wound, or a corresponding proportion of it if shunt wound. Mechanical brakes are of various forms, mostly operating upon the principle of two friction surfaces, both of which are free to move when the crane is hoisting, but one of which becomes fixed automatically when lowering, by the action of a ratchet and pawl, a friction gripping device, or other similar means. These brakes act in conjunction with those above described. The magnetic brake holds the armature from rotating, and the mechanical brake is so connected with the hoist gearing that, when the armature stops and the drum continues to rotate, a screw or cam action forces the friction surfaces together with a pressure varying with the load, and tending to increase until the drum is brought to a sudden stop. This action has taken time to describe, but it is in effect almost instantaneous; that is, the drum stops in a small fraction of a turn after the armature ceases to rotate. In steady lowering, a small current is sent through the motor which releases the magnetic brake and permits the armature to rotate, at such a slow rate, however, that it constantly tends to lag behind the speed imposed by the falling load; in fact, the latter has to partially drive the motor. Thus a balance is established, the current fed to the motor being just sufficient to produce such a speed as will cause the mechanical brake to retain its pressure to the point which allows the load to fall at the desired rate. The action is smooth and continuous, not a succession of stops and starts, as might be imagined. With very light loads, of course, the brake does not act at all, the friction of the machine furnishing sufficient resistance. The motor must then work to lower, the same as in hoisting, but in a less degree. Sometimes brakes controlled by the operator's foot or hand are used in place of the magnetic ones, the pressure being applied by means of rods and levers, or a light rope running over sheaves to the trolley. Occasionally the rope

s used in addition to the solenoids to control the brake without the aid of current.

One traction wheel on each rail is driven by a squaring shaft which runs from side to side of the trolley, and this arrangement is still more essential for the bridge; a driving or squaring shaft running from end to end beside one of the girders. This shaft should be driven from the center to insure equality of motion at each end; and when, as is often the case, the motor is required to be at one end of the bridge, a second shaft is carried out to drive the gear at the center. It need not be said that ample bearings are desirable, and free lubrication a necessity. Where access to the bearing is very direct, compression grease cups are among the best means available.

The bridge should be provided with substantial trolley stops, and the runaway in the building with still better ones for the bridge. Operators have been known to let the crane drive up against the end of the building, and it is well to place obstacles to this procedure before, rather than after the fact. Stops are generally fastened to the rails and should strike against the tread of the wheels, not against the flanges. Turning up the end of the rail itself makes a very excellent stop. Spring buffers are used in some cases and are always desirable, the only drawbacks being the items of expense and the room occupied. They are almost essential where two cranes are liable to come together on the same track. Trolleys and end trucks for cranes, have, in the past, been designed with their principle elements formed of cast iron; and, indeed, with their numerous gears and shafts, requiring many bearings of complicated forms for their support, this material lent itself most readily to the necessities of the case, but the more recent constructions consist of the fewest and simplest possible parts, supported upon a structural steel frame, which is at the same time a lighter and more reliable material for the purpose.

The distinctive feature of a traveling crane is the bridge, and it is in other respects also one of the details most worthy

of consideration. The two characteristic forms of crane bridge girders are the plate and box sections, each with merits of its own, and for special cases of extremely wide span, the various latticed truss constructions are used. Plate girders can be designed that are economical of material, especially so for the small capacities, and they have the advantage of presenting all their parts for periodical inspection and covering with paint or other rust preventative. They require, however, extremely wide upper flanges, usually with double angles to offer resistance laterally, both to the stresses due to suddenly starting and stopping, and the compression as the upper flange of a center loaded beam. The web should be well stiffened with vertical angles at close intervals for its entire length, but more especially near the ends. Box girders are a very rigid form, and are much used on this account. They cannot well be inspected for corrosion on the interior, and with the inside stiffeners or diaphragms sometimes used this is altogether impossible. For this reason they should not be used where there is danger of exposure to chemical fumes or excessive moisture. Since the load comes upon the upper cover plate between the webs, cast iron separators are riveted in to support the rail. These should be planed smooth and fit closely to webs and cover plate. Girders are classed respectively as straight, or rather inelegantly, as fish-bellied ones, the terms being self-explanatory, and the style to be preferred being governed by circumstances. They should be rigidly connected to their end trucks with keys and turned bolts, or securely riveted in place. It is well to have the ends of the two girders connected rigidly together to stiffen the upper flange, which acts much the same as a strut or column. In cases where the trolley is not required to travel the full length of the bridge, the upper flanges may be connected together at points as near the center as the trolley motion will admit of. Rivets should be liberally used, the widest spacing, occurring at the center, not to exceed six inches pitch, reducing gradually to about three inches at

the ends, to provide for the increasing shearing stress and the frequently smaller depth of girder. The most recent constructive methods favor making the girder flanges of the three pieces, viz., one cover plate and two angles, and procuring these sufficiently large and heavy rather than multiplying their number, and they are each required to be of one piece the full length of the bridge. As regards the girder webs, well made butt joints with plates on each side may possibly not be any positive detriment, but they cannot be said to be of any advantage and should be avoided when it can be done easily. They should not be allowed to occur at points of maximum shear, viz., near the ends of the girders. Flange angles and cover plates are better in one piece wherever possible, and if a splice must be allowed, it should not be permitted near the center, and must be made with butt plates and cover angles of ample length, so that the rivets, through them on either side of the joint, will present a shearing and bearing value more than equal to the flange stress due to the bending moment at this point. Constructions involving countersunk rivets are best avoided; and, fortunately, the increased cost has a tendency to reduce the number of this form of rivets to a minimum. Rails also are usually in one piece, and should be securely fastened to the girders. They may readily be riveted to plate girders; and, on box sections, tap bolts are used through top cover plates to the cast iron separators.

Among other features which deserve more attention than is generally accorded them may be mentioned the following: The cage should be strong, which is not inconsistent with light construction, and provide a reasonable space for the operator in addition to the controllers and resistance boxes, it requires to be well braced to prevent swaying, and be provided with an angle or plate projecting above the floor to prevent tools or other articles being pushed off. A platform, easily reached from the cage, should extend from end to end of girders on the shaft side. A substantial railing is required, and the same

guard angle along the floor called for on the cage applies here also. The bridge motor, shaft bearings, trolley and all parts of the crane are thus made easy of access to managers who are not also acrobats; and this is important, if the machinery is to be kept in good condition. The foregoing remarks, it will be noted, condemn the existence of any loose part, or parts, that may shake loose or become detached in any way, in the design of the crane. The arrangement of the lifting chains requires to be such that they will hang as nearly vertical as possible, as any marked deviation produces additional stress; and they are necessarily in the position most aggravated by this cause when the load is at its highest point. The principle of piling up, in place of hanging up, should prevail in crane design. That is, the trolley should rest upon the bridge, and the bridge girders rest upon end trucks, in place of having wheel brackets bolted to their sides, as is often done; and in general, loads should rest upon their supporting beams rather than be suspended from them. The drum is best placed as high as is feasible on the trolley, and the shackle should lift close up to it, leaving all the space possible available for hoisting. Most modern cranes have an ample wheel base, which prevents them from assuming an oblique position on their tracks, but is at times objected to as lessening the length of their run, an item of importance only in a very short building, and it has the marked advantage of distributing the load upon the runway. The wiring of a crane should be reasonably well protected from possible accident, be in plain sight, of the simplest possible character, and should include a double pole switch, circuit breaker, fuses on the main circuit, and also on branch circuits to each motor, all placed so as to be easy of access.

The speeds at which cranes are run vary between wide limits; and when one is to be installed, it is well to see that we get approximately what is required in this respect. Common speeds for medium capacities are ten to fifty feet per minute for hoist, one hundred to two hundred for trolley travel, and

one hundred and fifty to three hundred for the bridge. See that the trolley will give the maximum lift required, and place the runway sufficiently high to make this lift available. It is often advisable to provide numerous small hoists for special service beneath the crane. Some small compressed air hoists, or even differential blocks, suitably disposed, will often relieve a crane of part of its work and avoid the necessity of installing a second one. The use of some standard and widely used type of motors and controllers is to be strongly advocated, as it reduces the number of spares required to be kept on hand, and enables renewals to be made with the greatest possible dispatch.

Special forms of cranes, designed for purposes other than merely lifting and transporting, each constitute a separate subject in itself and will receive only a passing notice here. The most common use for which they are built is for charging and drawing underground heating furnaces. They are practically complete machines, and resemble cranes in the accepted meaning of the term only in being carried upon a traveling bridge, and operated from a cage. They have a more or less rigid tongs or other gripping device, capable of being opened, closed, rotated, raised or lowered at the will of the operator. The tongs are raised and lowered by being rigidly connected to one or two nuts traveling up and down vertical, coarse-pitched screws, or sometimes the nuts are fixed while the screws move; while in other designs the tongs are connected to a rack raised and lowered by means of a pinion. These screw machines are much used for handling ladles of molten metal, as the nature of their construction renders them extremely steady and reliable, and it is practically impossible for their load to drop at an excessive speed, or otherwise than with a nearly uniform motion. As this motion is arrested so absolutely at both the top and bottom of their stroke, they should be designed with a lift somewhat in excess of that actually required; and it is sometimes advisable that a tell-tale be placed upon them which

warns the operator when he is approaching the limit, and so avoids opening the circuit breaker, or, should the breaker fail to act promptly, possibly damaging the motor. The same object is accomplished by means of electric cut-outs, which automatically open the circuit and deprive the motor of current before the limit of the stroke is reached.

The electro-hydraulic crane is a special form, combining the merits of hydraulic service with the flexibility provided by electric transmission of power. It consists of a water tank, cylinder, with the necessary hydraulic valves, pumps for producing the pressure, and electric motors and gearing for operating the pumps. This seems a round-about way of producing results; costly to install, wasteful of power and involving the the transportation of a large mass of dead load; but there are cases in which the advantages outweigh the drawbacks.

In the foregoing paragraphs, an effort has been made simply to indicate some of the principal features of overhead traveling cranes, as an aid to a ready selection of the best that may be offered, and to assist in a comparison of their various claims for approval. Reference has been made to features which it is well to avoid, but it is not meant to condemn machines which may embody them. Many very efficient tools have been constructed which include in their make-up one or more such details, but these, like many other good things in this world, have merit in spite of their faults, not because of them; and we must consider that our judgment of any human contrivance must be based upon a judicious study and balancing of its merits and demerits. The need and demand for traveling cranes is growing rapidly and steadily. They are among the greatest labor savers yet devised; using power in proportion to the work they do, costing little when not in use, and working well under seemingly very adverse conditions, they pay a liberal return on the cost of investment and maintenance.

The runway, while not a part of the crane proper, de-

serves to receive a passing mention. It should be made amply strong, and in this connection, it is well to remark that money is better used in paying for material than for labor, since a building composed of massive parts is better calculated to resist shock and absorb vibrations than a light skeleton structure of equivalent strength. Ample head room above the rail is an advantage, as it is always possible that the crane may sometime be changed for one requiring more space. Cranes have been designed with the trolley between the girders in place of above them; these economize room, but it is not well to be thus limited unless it is unavoidable. Old buildings, in which cranes are to be installed, should be sufficiently strengthened to meet the new work imposed, and in this, sway bracing plays an important part, no less than the direct runway supports, as the constant motion tends to distort buildings not well braced.

The operating of a crane is not less important than the selection of it; and here some of the most obvious principles of management are frequently overlooked. The custom of regarding any boy who has wit enough to move the handles of the controllers, as being competent to manage a traveling crane, is one that is not to be commended. The operator should be more than a child in age, possessed of a share of mechanical sense, and of a certain stability of character, as the position is one in which carelessness or recklessness may be productive of damage, or even risk to the lives of others; and this is, perhaps, nowhere more true than in the case of foundry ladle cranes. It is generally recommended that crane chains be removed and carefully inspected and annealed at intervals of one to two years. They should be kept well greased while in service, as this, by causing smoother working and fewer small shocks, lessens the tendency to crystalization of the iron. Bearings and sliding surfaces which call for lubrications should be given it liberally, and grease, as well as dirt, be religiously removed from all other parts of the machine. The management should provide brooms, waste, etc., for cleaning, and insist that they

be freely used; and this will most surely be done when the operator is subject to frequent visits from someone in authority. To this end, substantial and easily climbed ladders or steps should be provided, in order that nothing may deter one from making these rounds of inspection as freely as need be. There are cranes in operation which require a man with some of the characteristics of a monkey to reach them, and the operators offer no protest, as they realize that they are thus more safe from molestation or supervision. Painting cranes and other machinery white is a practice which deserves to be encouraged; and it would be well if more generally followed, as it lets light into dark places and tends to encourage the removal of dirt and other foreign matters. It is well if the building is provided with skylights; and if not, it will pay to put in at least one, and have the crane kept under it when not in use. No one can clean well in the dark, and dirty machinery is always more or less dangerous machinery. The selection of a crane occurs once, but the keeping of it in order is required as long as it is in service, and vigilance should not be relaxed.

DISCUSSION.

Mr. Hirsch—Will you kindly give us a little more information regarding the relative values of the chain and wire rope cables?

Mr. Flanagan—I do not know that I can give you any very exact information. Chains are used in the majority of cases, especially with high-power cranes. Of course wire rope rolls up more compactly on the drum and has other advantages, but it is used in only a small proportion of cases. The wire rope is used frequently on some of the large hoisting machines known as shears winding over multiple sheaves as in passenger elevators, but for general heavy crane work the chain seems to be considered the best and stands abuse best. A notable example of the wire rope hoist is the hundred ton shears at Sparrow's Point, which unloaded the great Krupp gun.

Mr. Camp—It is my opinion that the wire rope has pronounced advantages over chains, but, on account of the fixed ratio of the diameter of the rope to the size of the sheave, its use is prohibited in the heavy cranes on account of the lack of room for the numerous sheaves.

Mr. Flanagan—Mr. Camp has just hit the nail on the head. As stated in the paper, the drum should not be less than 20 times the diameter of the chain. With the wire rope, the sheave would be much larger, and, while a suitable drum might be provided, the shackle constructed with such large sheaves would be unsightly and cumbersome.

Mr. Bole—The necessary diameter of a sheave makes the rope almost prohibitory for most purposes. It would make it impossible to let the sheave down into a limited area. Some hree or four years ago Mr. Diescher, a very experienced member of our Society, who has had quite a good deal of experience with wire rope in connection with inclined railways, stated in a paper, that the wire rope gave a forewarning of approaching decay much sooner and better than a chain did. It is possible to have a number of the strands in a wire rope broken, and still it will be servicable if the breaks were not too near each other; the rope would still be strong in spite of the breaks. But while a wire rope will give warning of its approaching decay; a chain very often breaks without any warning. The wire rope is being used so extensively in elevators, inclined railways and similar machinery that it certainly deserves consideration, but both the chain and the wire rope have their limitations.

Mr. Flanagan—Several years ago, I believe it was in 1896, Mr. Diescher showed us in this room some pieces of wire rope removed from one of the inclined planes. This rope would doubtless have endured the service for a considerably longer time but the desire to be upon the safe side had led to its being replaced when a certain number of fractured strands appeared within a given distance. As. Mr. Diescher explained, it is not

the direct tension that causes fracture, but the repeated bending causing brittleness, which is indicated by the fact that the broken ends of the wires do not part for a considerable time after the break occurs.

COL. ROBERTS—I would like a little information on the tensile strength of wrought iron crane chains. I recently had occasion to investigate this subject a little and the information received was very decidedly mixed up. Many advised against a chain of the highest tensil strength, and one or two manufacturers refused to bid on such a chain.

MR. BOLE—An old maker of chains used to make chains for us out of what was guaranteed to be the best Sligo iron, bought specially for the purpose. This was guaranteed to be of the very best quality, of high tensile strength, and apparently made an excellent chain. We used that same iron in our forge shop. Small forgings from it frequently became brittle when cold and would snap off under shock, but if it was thrown into the water, the iron became tougher and more fibrous. I take it that a good welding quality would be one of the most desirable qualities in a chain, as would also be the absence of a tendency to crystalization and deterioration.

MR. FLANAGAN—Chains for ordinary use are not made of material of high tensile strength, but of that which is tough and ductile, and the usual course is to simply get from reliable manufacturers their best product, as they are fully aware that chains are liable to a great degree of misuse and abuse, and they endeavor to meet these conditions. For some special requirements it may be admissible to use steel of higher tensile strength, but at what sacrifice of toughness this increased strength is secured must be determined for each case by the service required of it and the care it will receive in use.

MR. JOHNSON—I think that the judgment of crane builders in this matter between the advantages of the chain as against those of the wire rope is due largely to conservatism. They do not like to change from the chain to the wire ropes.

Some time ago I had something to do with the designing and purchase of a heavy traveling crane. It was designed for a wire rope but when it went to the manufacturers they would not bid on anything but a chain. In my opinion the wire rope is far and away ahead of the chain in the matter of utility and reliability. It never breaks until it is worn out, and it is very easy to inspect it from time to time. You can get a good line on it from just running your hand along. I think the adherence of the crane manufacturers to the chain is largely a matter of prejudice.

MEMBER—One thing should be taken into consideration in the running of electric cranes, and that is the operator. There must be a competent man to do the work. Careless running will do more to injure and wear out a crane than work will do. I saw recently a three and four ton electric crane operated very carelessly. It was started with a jerk and stopped the same way, with a resultant jarring and jarring that was very damaging to the apparatus. It was started up suddenly and stopped too suddenly. The crane was all right; it was bad handling.

MR. BOLE—The ability of the man who directs the working of a crane is a very important consideration. A number of foundry people have been killed simply because the man who was in charge of the machinery lost his nerve. All crane operators should be skillful, competent men, and should be well paid. In case of every crane accident almost the first question asked is, "Who was running the crane?" It is poor policy to put a machine that is liable to become an instrument of destruction into the hands of an inexperienced man.

MR. BOLE—The question of hooks is also a very important one. It does not, however, cut much of a figure with small weights, but when one is dealing with large weights the question of hooks and chain slings deserves a good deal of attention. Every hook and link must be of proper strength and condition or else an accident is liable to occur. Many

accidents that do occur are due to carelessness in selecting too light a sling chain because it is more easily handled by the man who makes the hitch.

MR. F. A. RUNDLE—I find it very hard to introduce a wire rope crane in a rolling mill and believe the objection is mere prejudice. In my personal experience of fourteen years, I have never had an accident with a wire rope crane, although I have had several with chains. It is a very difficult matter to inspect a chain. The links may become damaged or crystallized and the inspection would have to be very close to detect it. With a wire rope the least break in the strand is easily discernible. In regard to the brake, I believe the hand-brake is the better. It seems to me that it is a disadvantage to have the operator stand on one foot. In the foot brake the operator may put his foot down hard and bring the machinery to a very sudden stop. I think the machinery can be the better controlled with the hand brake.

MR. FLANAGAN—There is something to be said upon both sides of the question. I think the foot brake can be operated with as much care and accuracy as the hand brake, and it is often an advantage to have the hands free to operate the controllers.

On motion the Society adjourned.

REGINALD A. FESSENDEN,
Secretary.

MEETING OF THE CHEMICAL SECTION.

PITTSBURGH, PA., October 17, 1900.

The regular monthly meeting of the Chemical Section was held at 410 Penn Avenue.

Mr. Jas. O. Handy in the chair.

The minutes of the previous meeting were read and approved.

The chairman appointed the following members to assist him in obtaining papers: Prof. Phillips, Dr. Stahl and Mr. Gross.

After discussing many interesting subjects the Section adjourned at 10.20 P. M.

GEO. O. LOEFFLER,
Secretary C. S.

ABSTRACT OF DISSCUSSION AT THE MEETING OF THE CHEMICAL SECTION.

Palladium Asbestos. Prof. Phillips prepares it by rolling straight fibrous asbestos between two glass plates until the fibers are well separated. The asbestos is then moistened with palladium chloride solution, dried and ignited over a bunsen burner. If necessary the fibres are again rolled and the impregnation and ignition repeated. The speaker had found it unnecessary to use any reducing agent with the palladium chloride.

Carbon monoxide may be quantitatively recognized in gaseous mixtures by its power of reducing palladium when passed through a slightly acid solution. Palladium in alkaline solution is not reduced while gold solutions behave in exactly the opposite way, being reduced only in alkaline.

Palladium may be detected qualitatively by passing carbon monoxide through suspected acidified solutions. (Prof. Phillips.)

A Gooch filter packed with spongy platinum, recommended by Heraens, was described by Dr. Stahl. (W. C. Heraens, Zeit Aug. Chemie, heft 30, p 745.)

The Orsat gas apparatus was discussed. It was decided that its popularity was due to its compactness and portability and to the possibility of rapid manipulation. The reagents also are economically used, which is not the case in the Elliot apparatus.

The Dellwik Water Gas Process as described in the latest issue of the Iron and Steel Institute Journal, by Carl Dellwik, the inventor, was discussed after a brief abstract had been read by Mr. Craver. The inventor, by increasing the pressure of his blast, shortens the "blowing up" period to 2 minutes for each 10 minutes of gas making. The economy effected by this simple modification is enormous. Instead of obtaining an efficiency of 40 to 50% of the heat value of the coke used, the gas obtained by Dellwik represents 80 to 90% of the B. T. U. in the coke used in the generator and in the fuel used under the boilers. The gas made is a high grade water gas. The process has been investigated and favorably reported on by Prof. Vivian B. Lewis, of Greenwich, and Dr. George Lunge, of Zürich.

Alumina in ores, cinders, etc. Mr. Camp had applied the ether method for separating the greater part of the iron to materials of this class. The work remaining was by this means much simplified.

Acid water in the rivers. On account of the dry season, the acid iron water from the coal mines has come to form a large proportion of the river water. In order to protect their boilers manufacturers have to use soda ash. At Duquesne the river contained 8 parts of acid per 100,000 on the day of the meeting. Mr. Camp stated that foaming was not a necessary accompaniment of the neutralization with soda ash of water containing considerable amounts of acid. It was more apt to occur in locomotive than in stationary boilers. In either case blowing down should be frequent.

Abstracts by Jas. O. Handy.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The one hundred and ninth regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's House, 410 Penn avenue, Tuesday evening, November 20, 1900, ninety-seven members and visitors being present. The meeting was called to order by the President, Mr. W. A. Bole.

The minutes of the previous meeting were read and approved.

For the Board of Directors, the following applicants were reported as passed and to be voted for at the next regular meeting :

ALONZO L. CONNER, - - Mechanical Engineer, With American Tin Plate Co., McKeesport, Pa.

JOHN W. LANDIS, - - - Manager, Pittsburg Office, The Goubert Mfg. Co., 501-2 Murtland Bldg., Pittsburg, Pa.

WILLIAM GARDNER SHROM, With Westinghouse, Church, Kerr & Co, 358 Atlantic Ave., Pittsburg, Pa.

The following gentlemen were balloted for and duly elected to membership :

A. O BACKERT, - - - Manager, Pittsburgh Branch of The Iron Trade Review, Cleveland, Ohio, 429 Park Bldg., Pittsburg, Pa. House, 430 Arabella Street, Knoxville, Pa.

JOHN H. CARLIN, - - - Machine Dealer, Carlin Machinery and Supply Co., Allegheny, Pa., House, 435 Graham Street, Pittsburg, Pa.

MARTIN J. DOWLING, - - Superintendent, Bessemer and Open Hearth Department of Jones & Laughlins Co., Pittsburg, Pa. House, Ward and Cato Streets, Pittsburg, Pa.

CHARLES VAN CUE WHEELER, Superintendent, Projectile Department, Firth-Stirling Steel Co., Demmler, Pa. House, 1014 Ridge Ave., Allegheny, Pa.

The following memorial on the death of James Hemphill, prepared by Wm. Metcalf and Julian Kennedy, was read by the Secretary and ordered printed in the proceedings of the Society:

MEMORIAL ON DEATH OF MR. JAMES HEMPHILL.

James Hemphill was born in Mechanicsburg, Cumberland county, Pennsylvania, July 22d, 1827, and lived there until 1846, when his family removed to Tarentum, in Allegheny county, Penn'a.

In 1847, after locating at Tarentum, he was apprenticed to Mr. Samuel Black (still living at McKeesport, Pa.), at the blacksmith trade, at which he served for three years.

In 1850 he went to Pittsburg and was employed under Mr. Joseph French, then the engineer, and subsequently for many years the Superintendent of the Pittsburg Water Works. On Mr. French's appointment as superintendent, Mr. Hemphill succeeded him as engineer. During his employment at the Water Works, not being satisfied with confining himself to that business alone, he devoted himself in his off hours at home to casting baggage checks, having received flattering commendations from the late Thomas A. Scott, of the Pennsylvania Railroad, then Superintendent of the Pittsburg Division of that road, for the finish and neatness with which he turned them out. He has very frequently referred to Mr. Scott as the man who gave him his first start in life by enabling him to earn a little extra money.

About 1856 or 1857 he invested some money, with others, in a little machine shop, which was really the tool shop of the abandoned steel works of McKelvy & Blair, standing on the ground subsequently occupied by Hussey, Wells & Co., one of the first steel works in Pittsburg. In the course of a few years he withdrew from that partnership and in 1859 he entered into one with the late W. S. Mackintosh and N. F. Hart, in a shop at the corner of Twelfth and Pike Streets, Pittsburg, devoting his whole time to that enterprise. From this small beginning the "Fort Pitt Foundry" of Mackintosh, Hemphill & Company has grown.

The history of Mr. Hemphill for the last thirty years is practically a history of the iron and steel business of the United States. There is scarcely a steel works in the country, of any importance, for which he has not constructed more or less of the machinery.

As an engineer, Mr. Hemphill was noted for building high grade machinery, having always kept in the lead in building machines of rugged and massive proportions, and would always build a machine as he thought it should be, even if he lost money on its construction. The work which his firm turned out has always been noted as much for thoroughness of workmanship and excellence of material, as for strength and solidity, and no engineer in the world has probably ever built the same amount of machinery, which has run so uniformly well and with so few breakdowns. Mr. Hemphill was the pioneer in this country of the system of reversing mills, which have done so much to cheapen the cost of steel. He was prominently connected with the construction of the Homestead works and the Duquesne Works, now owned by the Carnegie Steel Company; also, of the Carrie Furnaces, all of which were very successful.

He was not only great as an engineer, but as a business man, and his judgment was always sought by many people in regard to business questions as well as mechanical ones. In

1893 he accepted the presidency of the newly organized National Bank of Western Pennsylvanin, to which his character for prudence and good business judgment lent no little strength.

To those who knew him it is superfluous to say that above even his abilities as an engineer and business man, were his unqualified integrity, business honor and sense of the strictest justice. To the latter is doubtless due the fact, that, in his own career as a manufacturer, there was never a strike of workmen against *his* establishment. Where whole crafts struck as a mass against all establishments of the kind in the city, of course, it was not to be expected that his works would be an exception, but no employer in the country ever had more of the regard and confidence of his employes, than he.

Your committee only expresses the feeling of every one who knew him, in saying that a great man and one who will long be remembered, is lost to us in the death of Mr. Hemphill.

WILLIAM METCALF,
JULIAN KENNEDY.

The Secretary read the following communications from the United States Department of Agriculture:

WASHINGTON, D. C., October 25, 1900.

DEAR SIR:

The Office of Public Road Inquiries is in receipt of calls for National Good Roads and Irrigation Congresses to be held at Chicago, Ill., November 19 to 24, inclusive. The calls are signed by Col. W. H. Moore, President of the State and Interstate Good Roads and Public Improvement Association of St. Louis, Mo.; George H. Maxwell, Chairman Executive Committee, National Irrigation Association; Hon. Carter Harrison, Mayor of Chicago, and Hon. John R. Tanner, Governor of Illinois. The Irrigation Association will meet in conjunction with the Good Roads Congress. The first three days will be devoted to road improvement and the last three days to irrigation.

During the present season road conventions have been held in the larger cities of the States throughout the Northwest. The objects of the Chicago meeting are similar to those of the other Western conventions, i. e., to promote more general interest in the improvement of the public roads, to discuss the best methods of building and maintaining them, and to promote good-roads legislation in the various States. Speakers of national reputation will be present to discuss good-roads questions from political, social, and commercial standpoints.

The governors of the several States, the mayors of cities and towns, the local road-improvement associations and societies, the boards of trade, the chambers of commerce, the farmers' clubs and institutes, the railway and other transportation companies, wheelmen's leagues, and all other organizations concerned or interested in the road subject are especially invited to send delegates, and the presence of all friends of the movement is earnestly solicited.

Hoping that you may be able to attend and participate in the proceedings, and that the objects of the meeting may be fully attained, I am,

Very respectfully,

MARTIN DODGE,
Director.

WASHINGTON, D. C.

DEAR SIR:

The Secretary of Agriculture has established in the Division of Chemistry a laboratory for testing physically and chemically all varieties of road materials. These substances include rocks of all kinds, gravel, shells, brick, clays, and other bodies used in road building in country districts, but do not include materials for municipalities. This laboratory will be ready for operation about the 1st of December.

Any person desiring to have road materials tested in this laboratory is advised to write to the Office of Public Road Inquiries, Department of Agriculture, Washington, D. C., for instructions in regard to the methods of selecting and shipping samples.

Specimens will be tested in the order in which they are received, excepting those sent by the special agents of the Department, which will be given preference over all others.

Samples of miscellaneous nature, not taken in accordance with the directions given by the Office of Public Road Inquiries, will not be examined.

A full description of the laboratory and its installation and the methods of conducting the tests will be given in a forthcoming publication of the Department.

Very respectfully,

MARTIN DODGE,

Director.

It was voted that a nominating committee of three be appointed by the president, to report at the next meeting the nomination of officers for the coming year. The President appointed the following Past Presidents to act on this committee: Messrs. Harry J. Lewis, Emil Swensson and Geo. S. Davison.

Next in order was the paper of the evening by Mr. Francis Hodgkinson, entitled, "Steam Turbines, with special reference to the Westinghouse-Parsons Steam Turbine."

STEAM TURBINES—

WITH SPECIAL REFERENCE TO THE WESTINGHOUSE-PARSONS STEAM TURBINES.

By Francis Hodgkinson.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA,
410 Penn Avenue, Pittsburg, Pa.

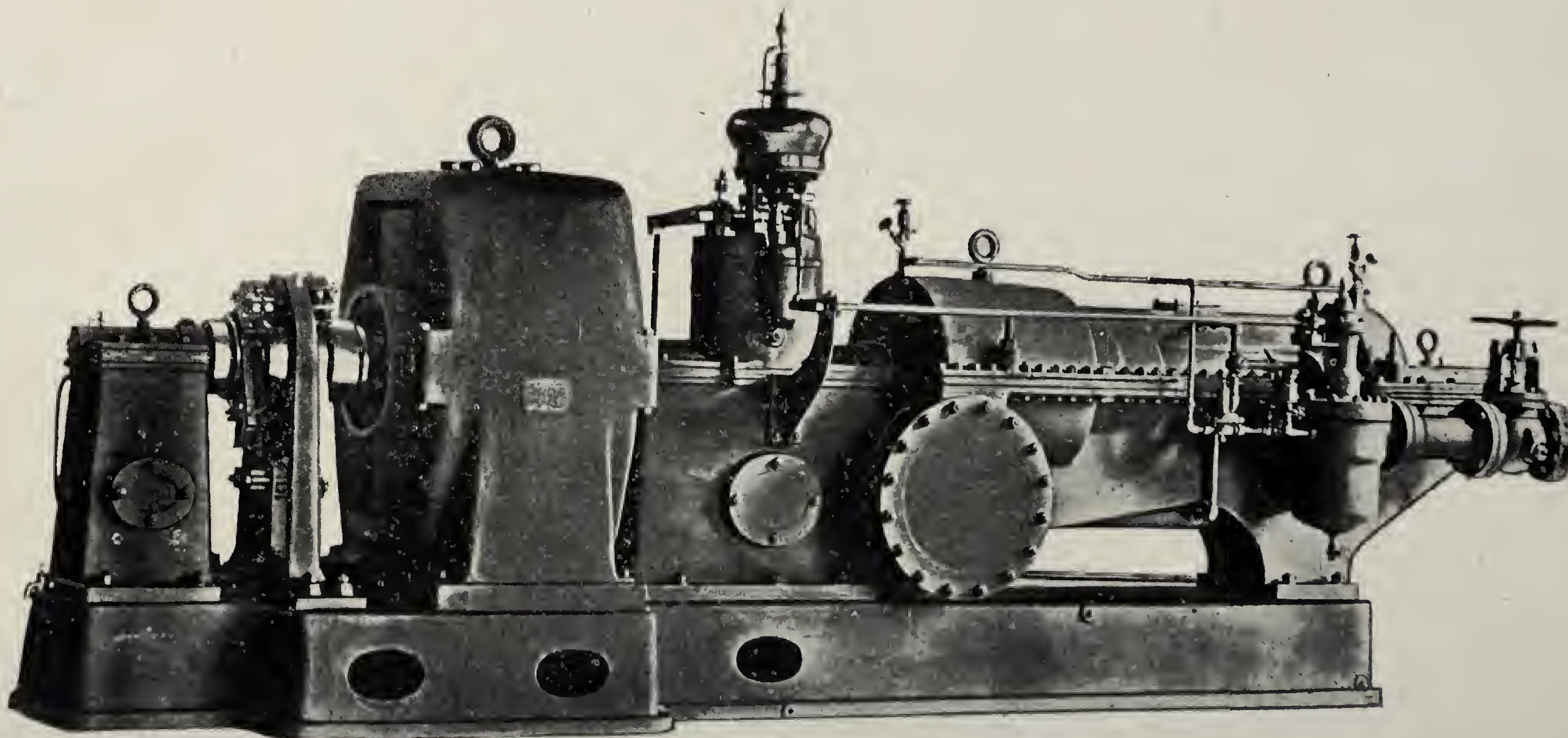


Fig. 19.

"STEAM TURBINES—WITH SPECIAL REFERENCE TO THE WESTINGHOUSE-PARSONS STEAM TURBINE."

BY FRANCIS HODGKINSON.

The earliest records of steam engineering are to be found among the relics of Ancient Egypt. About 120 B. C. Alexandria was at the zenith of her civilization. At this time Hero, probably contemporary with Euclid and Archimedes, wrote his celebrated work "*Spiritalia Seu Pneumatica.*" In it he described several forms of mechanical apparatus. The use of the steam jet for accelerating combustion; the expansion of air when heated in a closed vessel, several forms of steam boilers, various hydraulic apparatus for opening and closing temple doors. The most interesting among all these is described a reaction steam turbine. It consisted of a boiler, above which is a sphere mounted upon two trunnions. By means of these, steam is admitted to the interior of the sphere. On the equator were attached two bent pipes, such that the issuing steam reacted upon the sphere and caused it to revolve about its trunnions.

It is unknown whether this engine was ever more than a mechanical toy, although it is very possible it may have been used by the priests for driving, so-called magical apparatus where high speed was desirable.

The next turbine, capable of any practical development, and which may be regarded as the forerunner of the de Laval Turbine, was invented by Bianca in 1629. In consisted simply of a jet of steam impinging upon the vanes of a paddle wheel and blowing it around.

A century later, 1705, the reciprocating engine appeared,

and from that time until the last few years, practically nothing was done in the development of steam turbines.

Before leaving this brief historical review, it is interesting to record that Mr. Parsons, with a view of exploring the possibilities of a reaction steam turbine, constructed one on the lines of Hero's engine. The sphere was replaced by two hollow oval sectioned arms, mounted upon a hollow shaft, with jets at the outer ends, through which the steam issued tangentially to the plane of motion. The whole was enclosed within a cast iron case and connected to a condenser.

With 100 pounds per square inch at the jets, and 26″ vacuum in the exhaust casing, a speed of 5,000 R. P. M. was attained and 20 H. P. developed. The consumption of steam was 40 pounds per brake H. P.

It is not a little remarkable that the latest developments of steam engineering should be returning to the earliest form of engines of which we havé record. It is still more remarkable that the engine, as described by Hero, had greater economy than any steam engine produced for 18 or even 20 centuries later.

The fundamental principle of the steam turbine, in contradistinction to the reciprocating steam engine, lies in the fact that the latter does work by reason of the static expansive force of the steam acting behind a piston, while in the former case the work is developed by the kinetic energy of particles of steam, which are given a high velocity by reason of the steam expanding from one pressure to a lower.

Steam turbines may be divided into three classes:

1st. Impact, of which Bianca's is an example.

2nd. Reaction, of which Hero's is an example.

3rd. A combination of both of these, of which Parsons' is an example.

It is proposed in this paper to deal only with two forms which have attained some degree of commercial success; namely, the Parsons and the de Laval, particularly the former.

The general principles made use of in water turbines also apply to steam turbines. The buckets and guides must have as little skin friction as possible, and so arranged that the acting fluid may strike without sudden shock, and have its direction of motion changed without sharp angular deflections. One difficulty, however, presents itself, and is due to the tremendous velocity of steam as compared with that of water under ordinary heads.

The laws governing the best velocity of buckets are the same as for water wheels. In the impact turbine the ideal condition is when the peripheral velocity of the buckets is one-half that of the fluid comprising the jet. In the reaction turbine this velocity must be equal to that of the jet in order to give us this ideal condition. Now with high pressure steam discharging into a vacuum the velocities obtained are from 3,000 to 5,000 feet per second, as calculated by Zeuner's formula.

A turbine, therefore, built on the lines just enumerated would have peripheral velocities far beyond the limits of strength of material. As an example a 10 inch Hero's engine would revolve at 75,000 revolutions per minute.

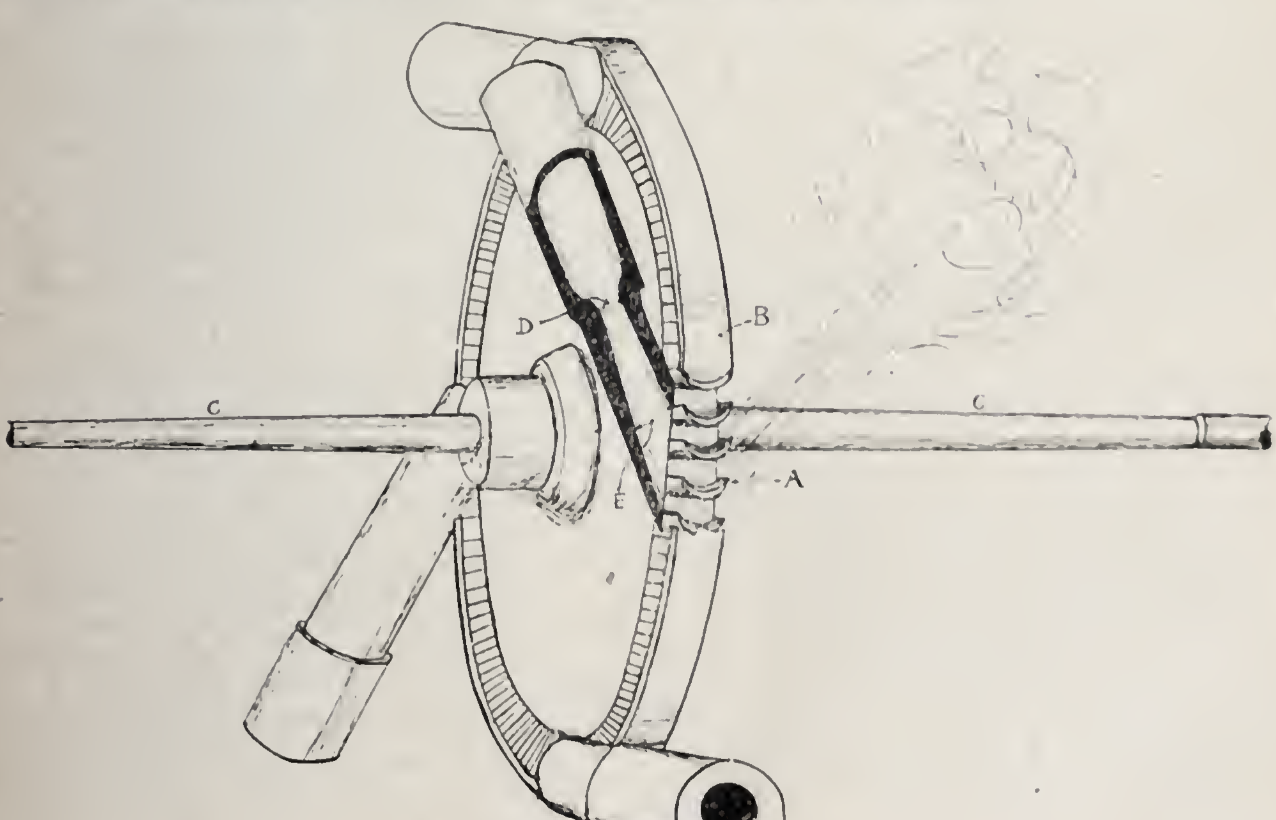


Fig. 1.

The de Laval turbine, shown on Fig. 1, consists of a divergent nozzle which directs the jet of steam upon suitably formed buckets "A" which are attached to the periphery of a revolving wheel. The outer edge of the buckets is shrouded by a steel ring "B", which prevents the centrifugal escape of the steam. The unique features of this turbine are the nozzle and the means by which the wheel is enabled to revolve upon its axis of gravity.

With regard to this latter point a difficulty always arises in attempting to revolve a body at a high rotative speed. It is essential, in the first place, that the body be accurately balanced, but in spite of all care this cannot be attained with absolute accuracy. The result is that with ordinary shaft and bearings, tremendous vibrations would be set up that would probably result in eventual rupture of the shaft. De Laval overcomes this difficulty, however, by mounting his wheel near the center of a long light shaft, "C" capable of being considerably bent and returning to its original form. The shaft is mounted upon bearings of ordinary construction. This flexibility enables the forces set up by the revolving wheel to deflect the shaft and enable the former to revolve about its axis of gravity.

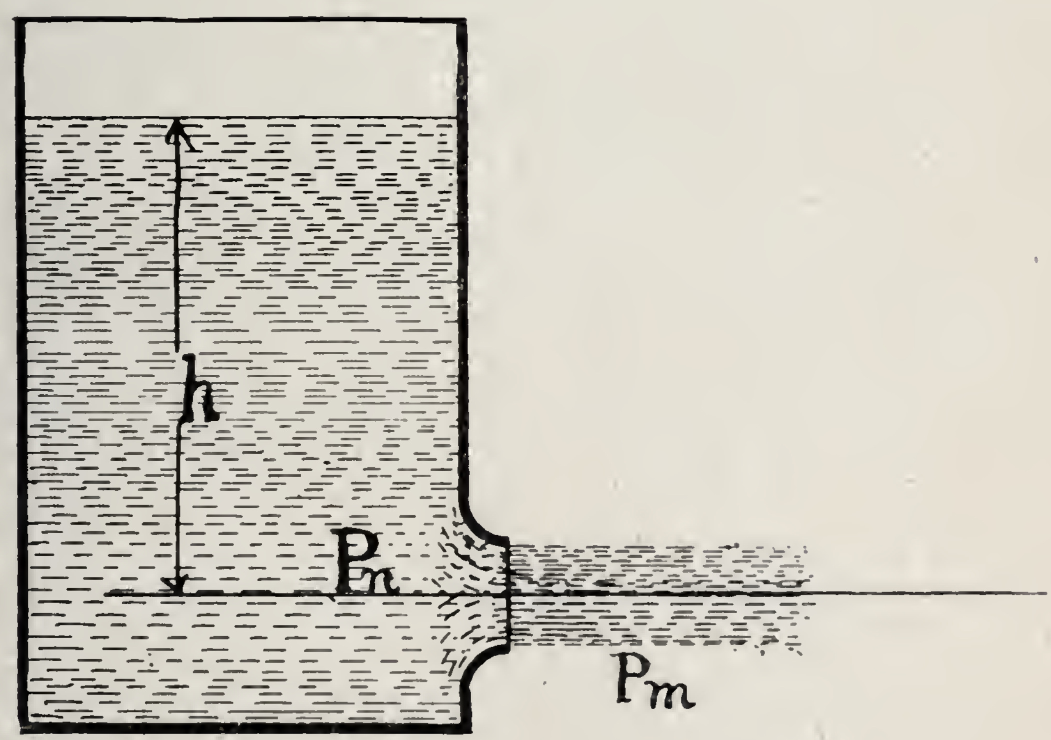
The nozzle is divergent. In it the whole expansion of the steam is carried out. The steam at the mouth of the nozzle has the same pressure as the exhaust. In other words the steam has its energy completely transformed into mass and velocity by the time it comes in contact with the buckets.

This brings up another feature of the turbine and is, that with the exception of the nozzles, and the throats of the nozzles, no parts are subjected to steam pressure. It is well known that the velocity of steam flowing through an orifice, from a greater to a lesser pressure, increases as the difference of the pressures increases, only up to a certain limit. This limit is reached when the lower pressure becomes less than $\frac{56}{100}$ths of the higher. Beyond this, however much the steam pressure is increased, the velocity of steam remains practically

the same—about 1476 feet per second. This limit of velocity is an anomaly, which seems to have been never satisfactorily explained.

It is probably due to the fact the pressure in the center of the throat is not the same as in the surrounding medium. The jet, after passing the throat, suddenly expands, and the change of direction of the fluid particles gives rise to centrifugal forces. Experiments all show that a jet, discharging from a reservoir of high pressure into a lower pressure, where the difference is greater than $\frac{56}{100}$, that the pressure in the throat of the nozzle is always equal to $\frac{56}{100}$s of the absolute pressure of the reservoir, no matter how great may be the difference between the two pressures.

The action of steam in the nozzle may be shown by further illustration.



In this case if the reservoir were filled with water, the velocity issuing would be found by the formula $V^2 = 2gh$ where h is the actual feet head of water above the nozzle. In the case, however, of the fluid in the reservoir being steam or gas instead of water, h must be changed to an ideal head, which is the column of fluid necessary to give the given pressure at

the level of the nozzle. This ideal head is equal to the feet head of water necessary to give the pressure, multiplied by the density of the water and divided by the density of the fluid in the reservoir. This formula, however, is only approximate, and is only good up to the before mentioned limits.

With small differences of pressure, such that Pm is greater than .56 Pn, the fluid will issue with a velocity varying with the square root of the ideal head, which will increase as the difference of pressures increase until we reach the before mentioned condition of maximum discharge, and up to this point the steam will issue from the nozzle in substantially straight lines; this of course providing the nozzle has a well rounded entrance, and is not a condition that might be termed "an orifice in a thin plate."

When the pressure is increased beyond this, the steam expands partially outside the nozzle, and the particles cease to issue in a straight line as before. This subsequent expansion is taken advantage of by de Laval, by means of his divergent nozzle, which is of the form shown in Fig. 1.

The throat is at "D," having a well rounded entrance, and from there on the nozzle diverges. The relation of the area of the outlet at "E" to the area of the throat at "D" should satisfy the equation.

$$\frac{Fm \quad Wm}{Vm} = \frac{F_2 \quad W_2}{V_2}$$

Fm = Sectional area of the throat.
F_2 = " " " outlet.
Wm = velocity of steam at throat.
W_2 = " " " outlet.
Vm = specific volume of steam at inlet.
V_2 = " " " " outlet.

This equation simply states that equal weights of steam pass at both the throat and the outlet in equal intervals of time.

Practically a nozzle must be made with the area at the

exhaust end as small as possible, for the sake of getting the greatest velocity, but just so large that the pressure will not be higher than that of the exhaust pipe.

The best length of nozzle is hard to determine. If too long there will be considerable loss of velocity due to skin friction. At the same time it must be long enough to admit of proper expansion of the steam. The best shape of the divergency has been the subject of investigation by various experimenters, in order to give the best expansion curve, regarded as a single particle. The writer's opinion is that the best results in this respect are obtained by a nozzle whose section is very near an ellipse.

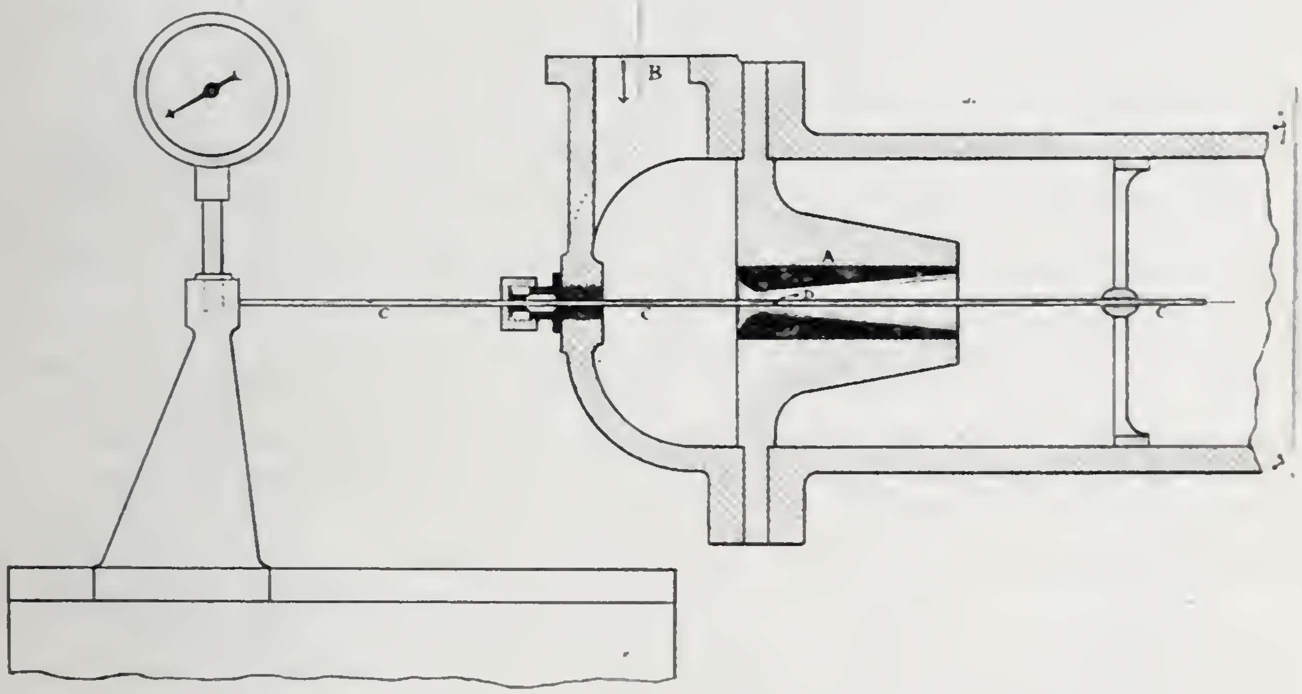
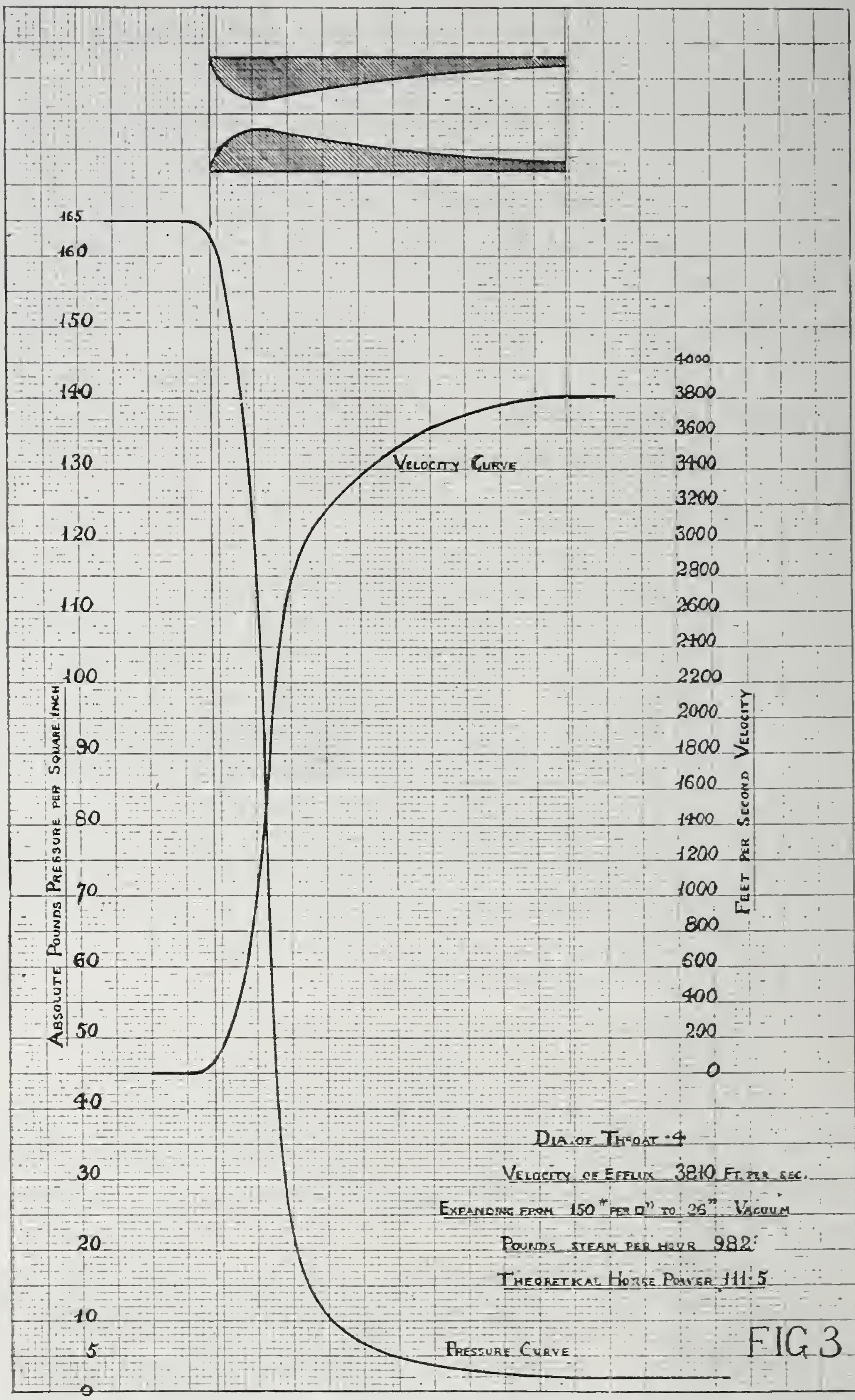


Fig. 2.

The investigation of the performance of steam nozzles is particularly interesting—the apparatus usually employed is shown in Fig. 2.

The nozzle for the experiment is at "A," the steam entering at "B" discharges through the nozzle directly into the exhaust pipe. At "C" is provided a small searching tube, sealed at one end, and with a minute hole "D" some distance from this end. At the other end is provided a suitable pres-



Absolute Pounds Pressure per Square Inch
165
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
5
0
Feet per Second Velocity
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Velocity Curve
Pressure Curve
Dia. of Throat ·4
Velocity of Efflux 3810 Ft. per sec.
Expanding from 150 # per □" to 26" Vacuum
Pounds steam per hour 982
Theoretical Horse Power 111·5

FIG 3

sure gauge or mercury column. Means are provided for sliding the searching tube with its pressure gauge back and forth, when pressures may be read with the hole in the searching tube in different positions throughout the length of the nozzle. From these figures a curve of pressures may be developed and from this, together with knowledge of the weight of the steam passing the nozzle per unit of time and the exact form of the nozzle, a second curve may be developed which will give some idea of the velocities of the fluid.

The curves on Fig. 3 give an example of this. They have, however, been developed theoretically on a basis of adiabatic expansion, that all the energy of the steam between the limits of pressure, viz: 150-lbs. gauge pressure and 26″ vacuum has been converted into velocity and that there are no losses due to skin friction or through loss of pressure by low co-efficient of efflux. This co-efficient of efflux is a feature of the entrance to the nozzle and varies from 50% in an orifice in a thin plate to 98% in a well-rounded orifice, as is shown in Fig. 3.

The pressure curve is an adiabatic expansion line from the throat to the outlet, and the pressure of the throat .56 times the absolute pressure of the steam before entering the nozzle.

The velocity at the mouth of the nozzle is shown to be 3810 feet per second and 982-lbs. steam passing per hour—diameter of throat $\frac{4}{10}$; theoretical H. P. 111.5.

In actual practice as much steam as this could not be made to pass for the reasons just given, so the nozzle would require some modification in consequence.

Of course in these investigations allowance must be made for the area of the searching tube. Fig. 4 shows an actual example of a nozzle designed for discharging into vacuum, but used for discharging into atmospheric pressure, and shows how the steam reaches near the condition of vacuum near the outlet and afterwards rises to the exhaust pressure.

This feature is to a certain extent taken advantage of in a de Laval turbine, designed for running non-condensing. The

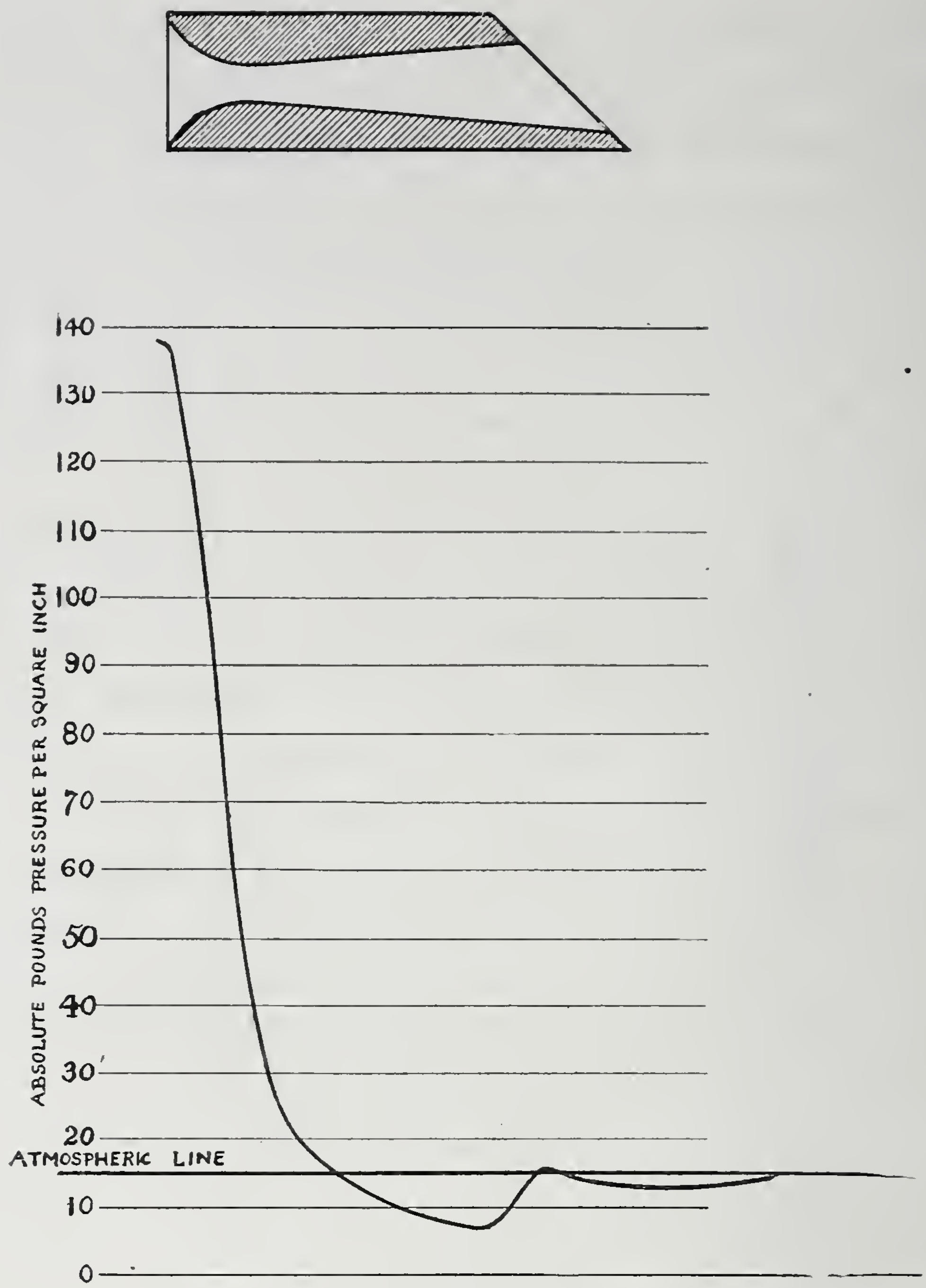


Fig. 4.

nozzle is slightly over-compounded so that the wheel may revolve in a partial vacuum. Some gain in economy is the result, by reason of the wheel revolving in a less dense medium.

Fig. 5 shows rather a curiosity. This form of nozzle was suggested as being as suitable as any that might have carefully constructed curved walls, and that the steam itself would take the correct passage and give the same results, so long as the correct ratio of throat area and outlet area were maintained. It will be observed how the pressure line forms waves, which exactly correspond with some lines shown in the nozzle which appears as though the steam particles fall very near to the ex-

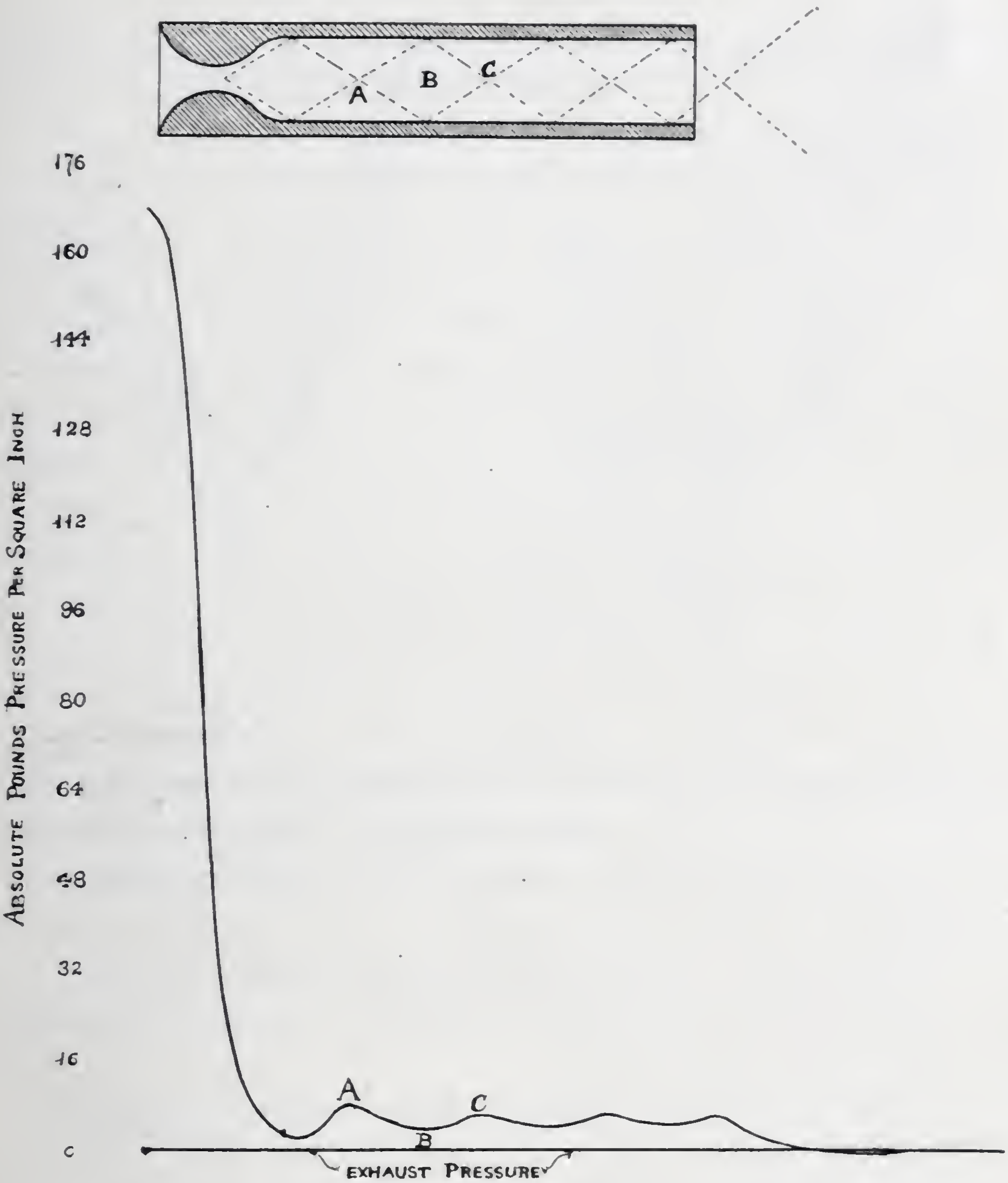


Fig. 5.

haust pressure immediately on leaving the throat. They strike the walls and rebound, meeting together at the point "A," when they form a point of pressure, again striking the walls at "B," meeting again at "C" and so on.

In the de Laval turbine the nozzles are set at an angle of 20° with the plane of motion of the buckets, which is as acute an angle as is possible.

The action of the steam on the buckets may be shown by

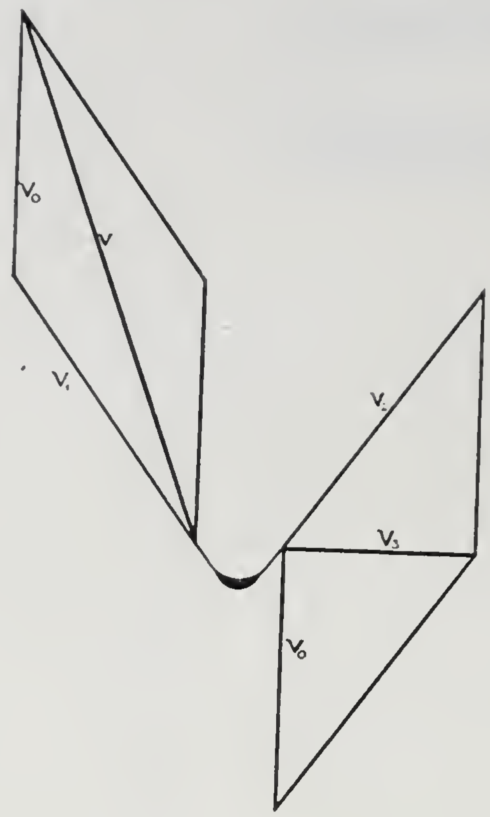


Fig. 6.

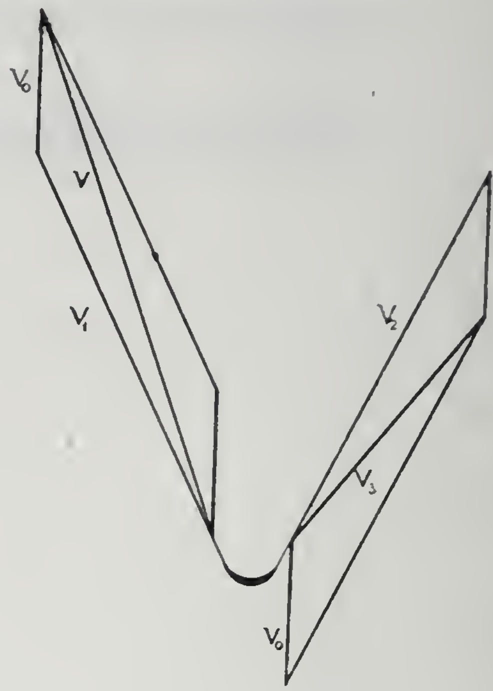


Fig. 7.

the diagram of parallelogram of velocities, Fig. 6, which shows an ideal condition which could seldom be obtained in practice.

V is the direction and velocity of the steam issuing from the nozzle.

Vo the velocity and direction of the buckets.

Component V_1 is the relative angle and velocity with which the steam strikes the bucket.

V_2 is the *relative* direction and velocity of the steam leaving the buckets.

V_3 is therefore the *absolute* direction and velocity of the steam leaving the buckets.

It will be observed here that V_3 is a horizontal line, so that the combination is one of maximum efficiency, the only losses being due to the angularity of the nozzle.

By reason of the tremendous velocities of steam, a diagram, similar to Fig. 7, is what is generally obtained in practice. It will be noted that the angle of the bucket at the entrance corresponds with that of the component V_1. It is usual to have the angle of outlet making an angle with the plane of

motion, equal to that of the inlet with the same plane, thus taking away practically all end thrust.

These turbines, especially the larger sizes, are equipped with several nozzles, some of which are provided with independent stop cocks, such that the number of nozzles in operation may be adjusted to suit the condition of running in order to obtain the most suitable steam pressure in the throats.

These turbines are essentially of very high speed. The smaller sizes run about 30,000 R. P. M. and are geared down to about 3,000; the larger sizes, about 10,000 R. P. M. The peripheral speed of the wheel is usually from 600 to 1,200 ft. per second. The reduction of speed is accomplished by means of a pair of helical spur gears with the angle of helix 45°.

These gears form by far the biggest part of the whole outfit. The remaining portions of these turbines have no remarkable features. The regulation is effected by means of a fly-ball governor which is on the slower running shaft and wire draws the steam at the admission.

Some tests of a 10 H. P. turbine were communicated to the A. S. M. E. in 1895, in which the turbine described had four nozzles of .138 diameter and one of .157 diameter of throat. The nozzles were two inches long from throat to outlet.

The speed of the turbine was 23771 R. P. M. reduced by gearing to 2400, the economy full load, non-condensing was 47.8 pounds per B. H. P. This economy is by no means bad when the small power of the outfit is considered.

In December, 1899, some tests were made in France under the following conditions: 192 lbs. boiler pressure, with 69° F. of super heat; mean H. P. 307.8; R.P.M. 772. The consumption of steam was 13.92 lb. per effective H. P.

The first Parson's steam turbine and generator was built in 1884. It developed 10 H. P. at 18,000 R. P. M. It ran for several years in Gateshead, on Tyne, England, supplying current for the manufacture of incandescent lamps. It is now

in the South Kensington Museum. It consisted of two groups of 15 turbines each, the steam entering between them and passing in opposite directions through each *group*.

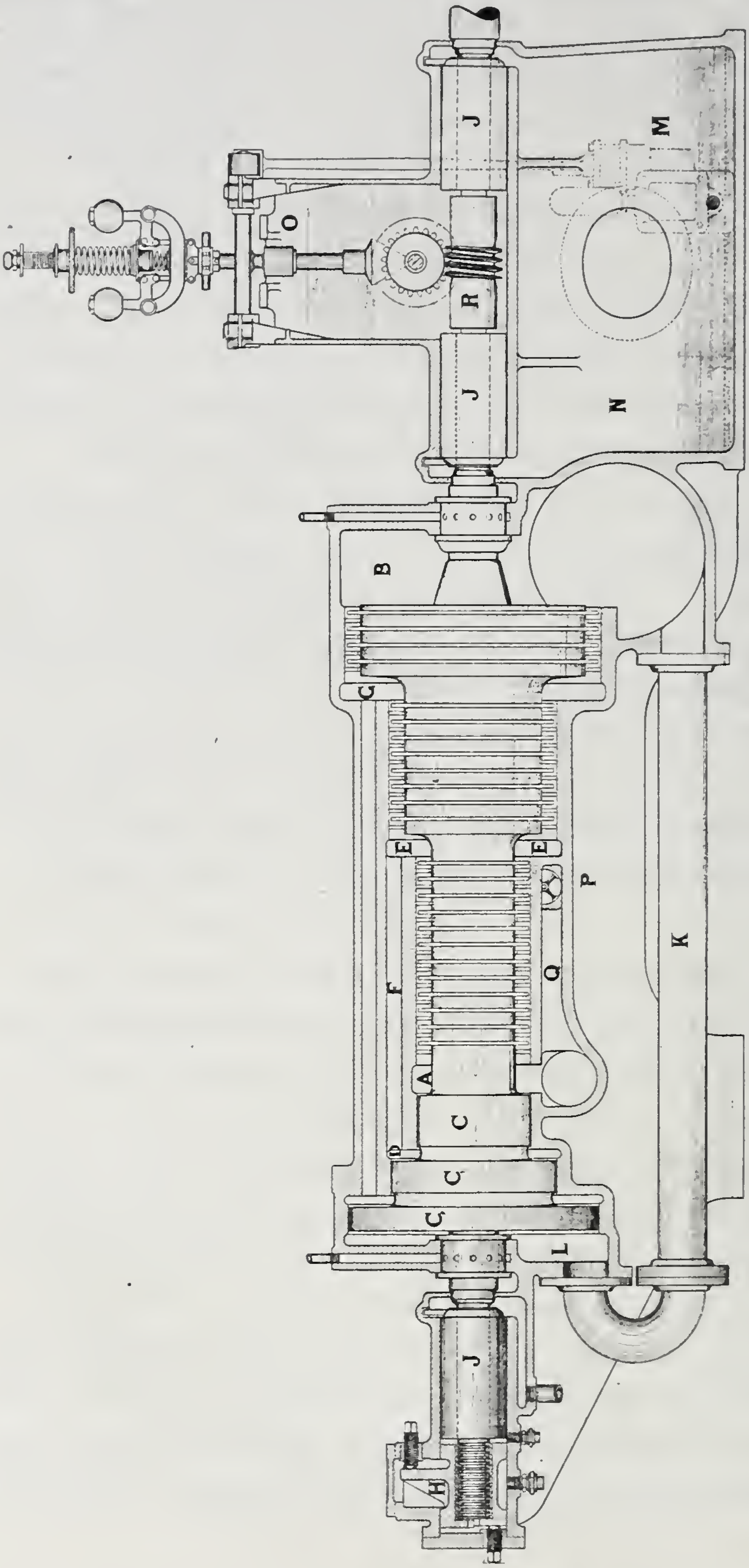


Fig. 8.

Fig. 8 is a general longitudinal section through a Westinghouse Parsons Steam Turbine. The steam enters at the governor valve and arrives at the chamber "A" and passes out to the right through the turbine blades, eventually arriving at the exhaust chamber "B." The blades are as shown in Fig. 15, the steam passing first a set of stationary blades and impinging on the moving blades, driving them around and so on. The areas of the passages increase progressively in volume, corresponding with the expansion of the steam. They will, however, be described more fully later. On the left of the steam inlet are shown revolving balance pistons "C." "C." & "C.," one corresponding to each of the cylinders in the turbine, which according to size may be 1, 2, 3 or 4 in number. The steam at "A" presses against the turbine and goes through doing work. It also presses in the reverse direction, but cannot pass the piston "C," but at the same time the pressure, so far as the steam at "A" is concerned, is equal and opposite, so that the shaft is not subjected to any end thrust.

The pressure "D" is equal to that at "E" by reason of the balance port "F" so similarly, so far as the steam pressure at "E" is concerned, there is no end thrust. This same fact also applies to "G."

The areas of the balance pistons are so arranged that no matter what the load may be, or what the steam pressure or exhaust pressure may be, the correct balance is preserved and the shaft has no end thrust whatsoever.

At "H" is shown a thrust bearing which, however, has no thrust to take care of, but serves to maintain the correct adjustment of the balance pistons.

The thrust bearing is in two halves, the lower half capable of adjustment in one direction, the upper one in the reverse.

The balance pistons never come in mechanical contact with the cylinder, and consequently there is no friction. The thrust bearing has ample surface, and besides is subjected to forced lubrication and does not wear. The adjustments once made always remain good.

There is obviously some leakage past the pistons, but it is found to be very small. Centrifugal force seems to have something to do with keeping down this leakage. The particles endeavoring to escape have to pass radially inwards in going through the small clearance. It is supposed then, that the rapidly revolving pistons have the effect of throwing outwards the particles with which they come in contact by reason of skin friction, so that the particles being slung outwards tend to oppose the escape of the particles inwards.

This theory, however, is somewhat imaginary, but in view of the economy obtained, the leakage cannot be very great.

At "K" is a pipe connecting the back of the balance pistons at "L" with the exhaust chamber (see Fig. 8), to ensure the pressure at this point being exactly the same as that of the exhaust.

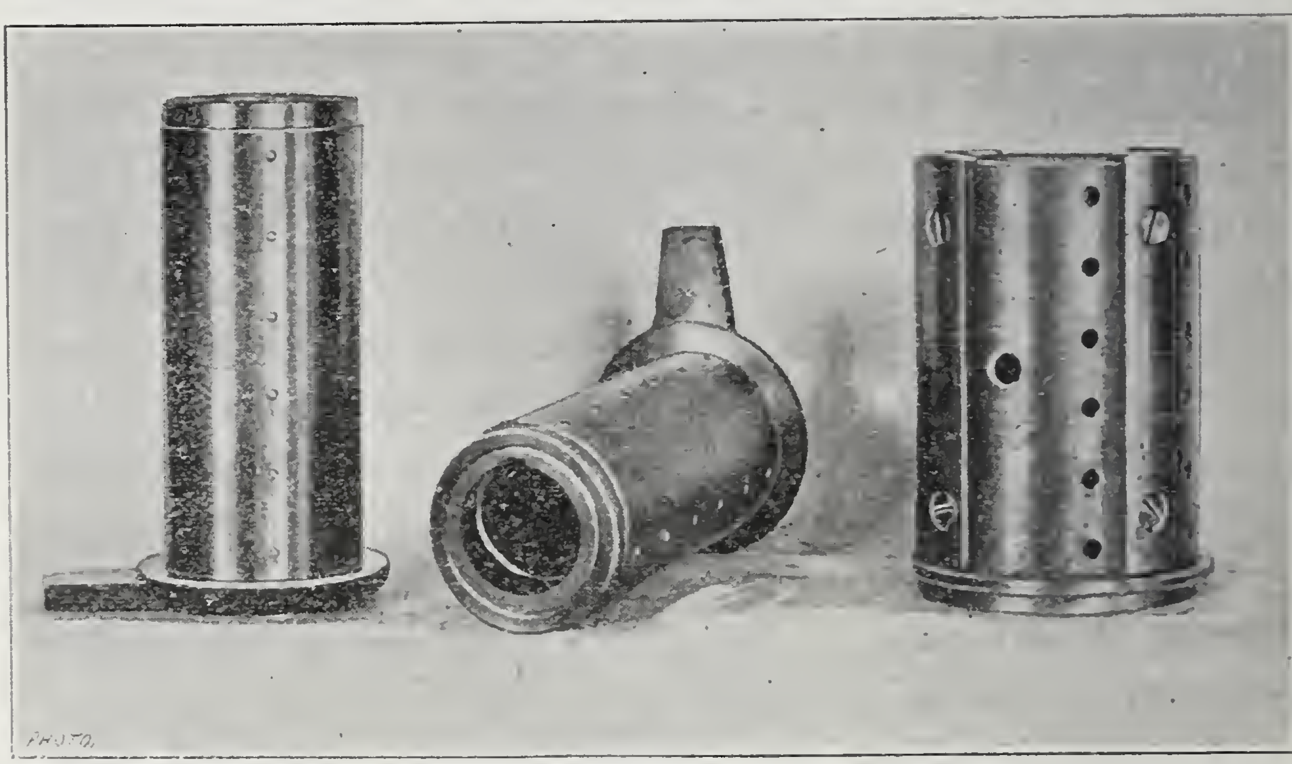


Fig. 10.

At "J" are shown the bearings. They are also shown separately on Fig. 10. They are unique in construction. The bearing proper is a gun metal sleeve, which is prevented from turning by a loose fitting dowel. Outside of this are three

concentric tubes having a small clearance between them. This clearance fills up with oil and permits a vibration of the inner shell, at the same time restraining same. The shaft therefore revolves about its axis of gravity, instead of the geometric axis, as would be the case were the bearing of every day construction. The journal is thus permitted to run slightly eccentric, according as the shaft may be out of balance. This form of bearing in a very remarkable manner performs the function of de Laval's slender flexible shaft. But in this case the shaft is built as rigidly as possible, so is not liable to crystallization which would result in eventual rupture.

The bearings have ample surface, are continuously lubricated under pressure, and it has been found in practice that they do not wear. As may be seen in Fig. 10, the bearings are surrounded by an outer cast iron sleeve, in which are fitted keys which may be shimmed up and permit any adjustment of the position of the shaft relative to the cylinder.

At "R" Fig. 8, is shown a flexible coupling by means of which the power of the turbine is transmitted. In small sizes the two shafts have a square cut on the ends, the coupling itself somewhat loosely fitting over these. In larger sizes it is generally a modification of this arrangement.

The governor gear and oil pumps generally receive their motion by means of a worm wheel gearing into a worm cut on the outside of the coupling.

At "N" is an oil reservoir into which drains all the oil from the bearings. From there it runs into the pump "M" to be pumped up to the chamber "O" where it forms a static head which gives a continuous pressure of oil to the bearings. The pump is single acting of the simplest possible construction, that will not become deranged. The oil runs in by gravity, so that it is unlikely to fail to continue pumping.

A by-pass valve is provided, shown at "P," which admits high pressure steam by means of port "Q" to the steam space "E". By opening this valve as much as 60% overload may

be obtained, and in the case of turbines operating condensing, full load may be obtained should the condenser be at any time inoperative, due to any cause, and the turbine allowed to exhaust into the atmosphere. Naturally the effect of opening the by-pass valve is to reduce the economy to an extent that will be seen later when discussing economy.

The glands consist of packing rings set in grooves cut in the shaft. The rings press outward and remain stationary. Any form of frictionless packing necessarily leaks a little. In the case of the turbine exhausting into a vacuum a little live steam is admitted between the rings by means of a small reducing valve, so that the leakage consists of a negligible quantity of live steam, instead of air which would impair the vacuum.

In the case of the turbine exhausting against anything above atmospheric pressure, a small ejector is provided, which drains the leakage steam from between the packing rings and allows it to drain through a suitable drain pipe instead of escaping into the engine room.

In all engines the governor is an important consideration. A fly-ball type of governor is made use of, as shown in Fig. 11, and has several features conducive to good regulation. The ball levers are swung on knife edges in lieu of pins. The governor works both ways, that is to say, the midposition of the levers is admitting a full head of steam to the turbine. A movement from this in either direction is tending to cut off the supply. This serves a useful purpose in the event of a very excessive load coming on the turbine, such as a short circuit which has the effect of bringing down the speed more than the percentage variation permitted by the adjustment of the spring when the steam immediately becomes shut off. Again in such an event as some of the governor driving mechanism becoming broken and the governor balls slowing up independently of the turbine, the steam is shut off before any damage could take place.

The speed of the turbine may be varied within all the

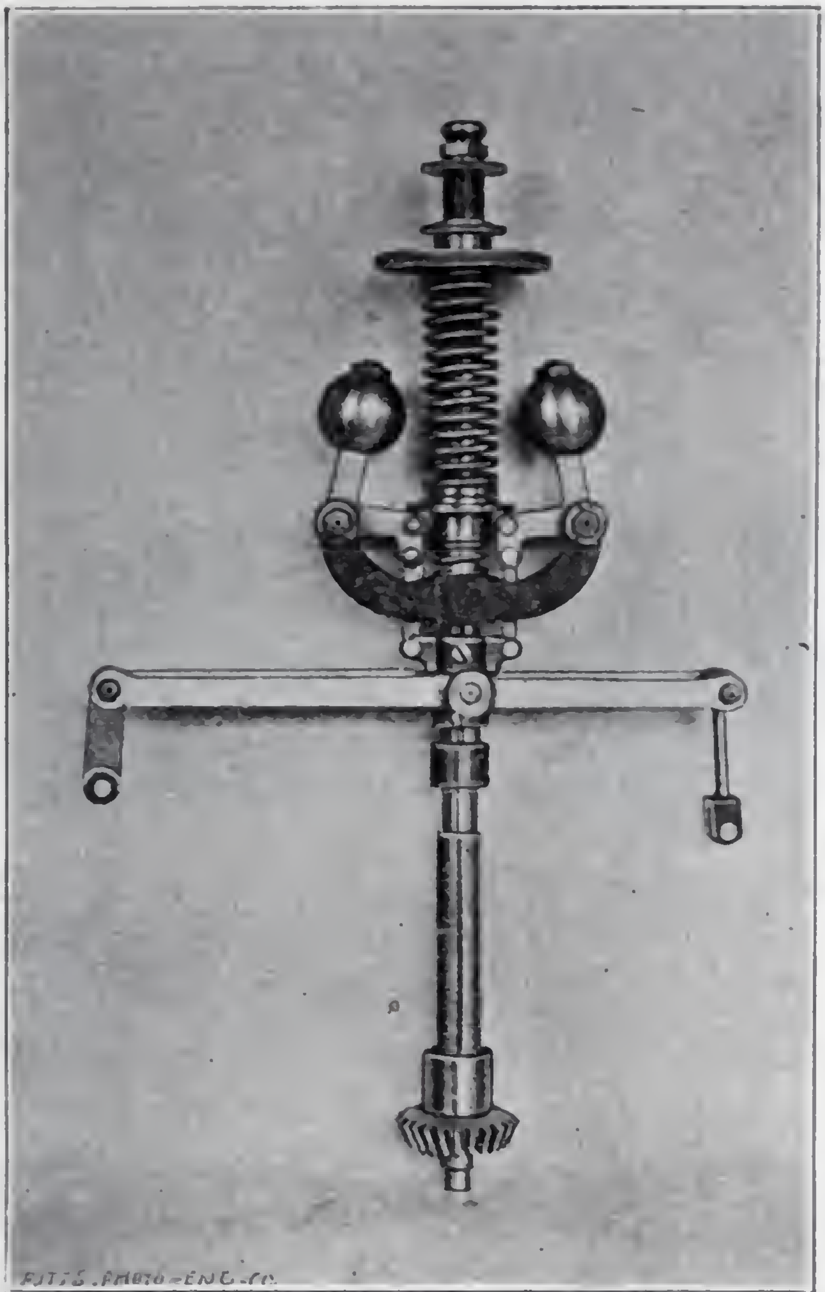


Fig. 11.

limits of the governor spring while the turbine is running. This is particularly useful in bringing alternators in synchronism and adjusting their differences of load when in multiple. This is accomplished by grasping the top knurled head, when by means of a ball bearing shown, the spring and tension nuts remain stationary. Any adjustment of the spring nuts may then be made, without in any way disturbing the running of the turbine, other than making the change that may be desired.

The arrangement of the governor levers is shown diagrammatically in Fig. 12. They are attached to a small relay valve

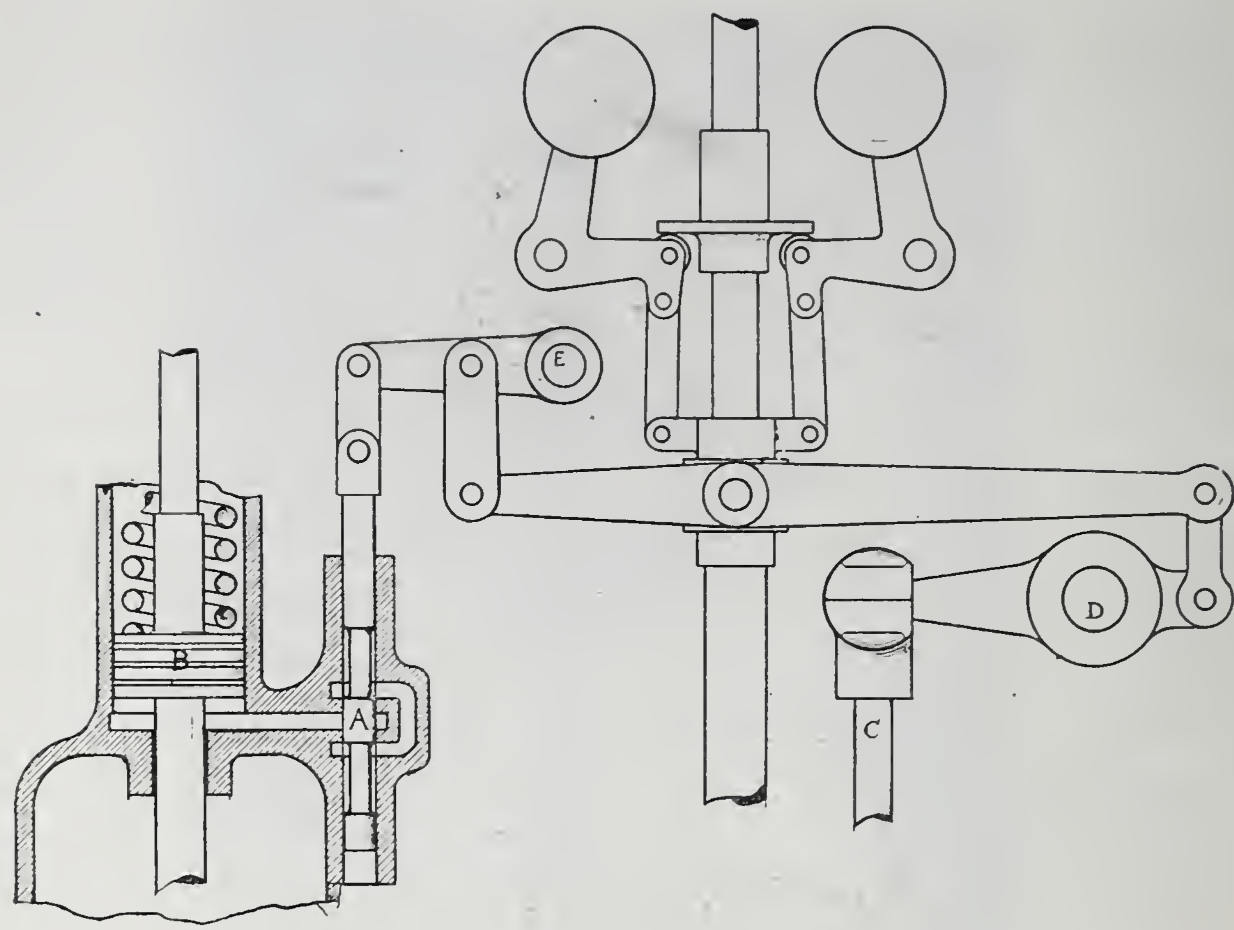
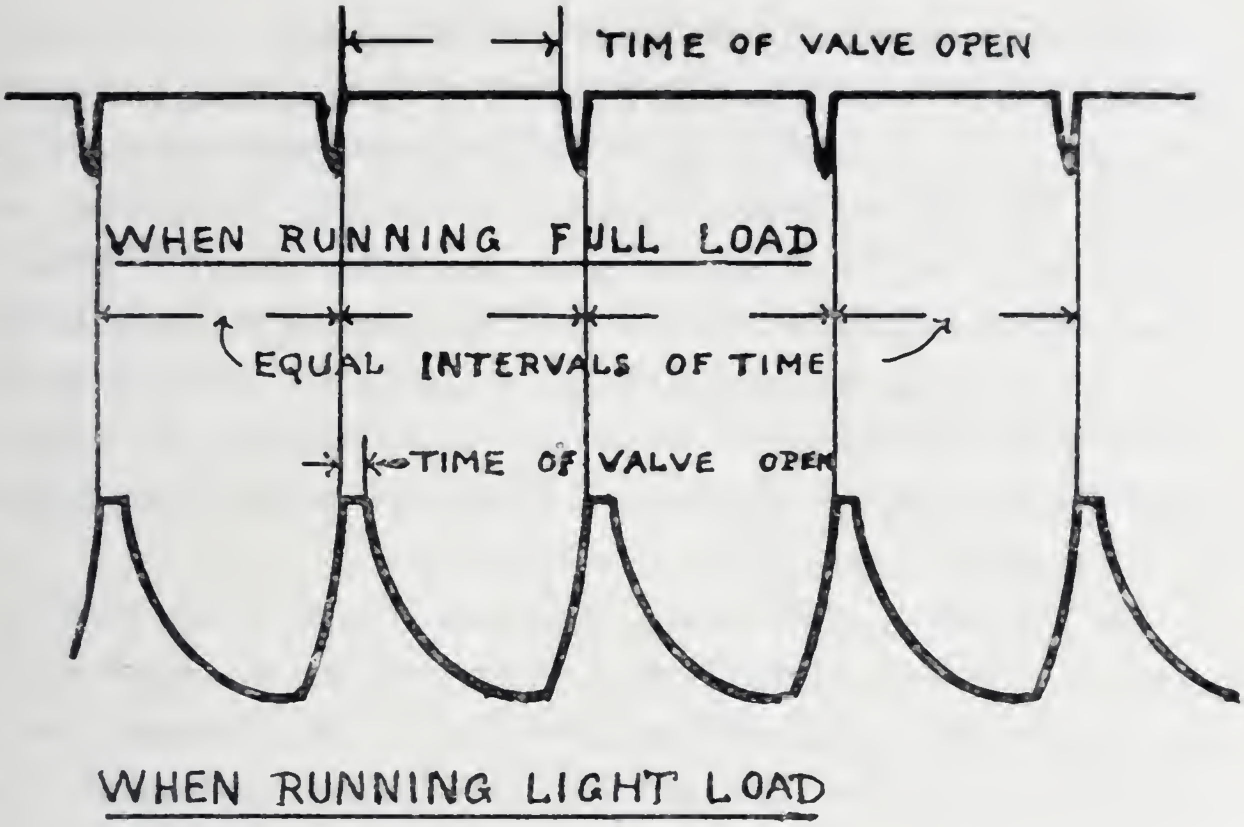


Fig. 12.

"A" which controls the steam below the piston "B", which is directly connected to the main admission valve. The levers receive reciprocating motion at "C" from an eccentric and use the governor clutch as a fulcrum, points "D" and "E" being fixed. Continuous reciprocating motion is thus given to the relay valve. This is in turn transmitted to the admission valve. The function of the governor is to vary the plane of oscillation of the relay valve, which causes the admission valve to remain open for a longer or shorter period according to the position of the governor. The steam, therefore, is admitted to the turbine in puffs, which occur at constant intervals of time. The puffs are of either long or short duration, according to the load. At full load the puffs merge into an almost continuous blast. If we were to attach an indicator to the steam space "A" Fig. 8, and pull the drum around by hand, we would produce a series of cards similar to



This does not mean that in the latter case there is a more complete expansion of steam than in the former; it simply means that high pressure steam is made use of at all loads. The complete expansion of the steam is taken care of independently in the blades.

The advantages of this intermittance are three-fold. The turbine is at all times using boiler pressure steam, no matter what the load may be. The admission valve is continuously in motion and consequently gets no opportunity to get stuck. The power to work the relay valve and overcome the inertia of the levers is transmitted through the governor clutch, hence the balls are moved in and out a very small amount at every oscillation of the levers, so that the governor levers in respect to their motion about their points of suspension are never at rest, and consequently when a change of load comes, the governor does not have to overcome the friction of rest, and is always ready to go to its new position.

These features are particularly valuable. So long as a piece of mechanism is continuously working we at least know it is in a condition to continue working and is not stuck.

There is absolutely no variation of angular velocity in the turbine, which is necessarily present in reciprocating engines, hence the value of turbines for running alternators in multiple. This can be realized when we know a 500 H. P. turbine will run 20 minutes after the throttle has been closed. This, of course, speaks well for the low friction, but is principally due to the tremendous fly-wheel effect of the shaft. All the power is transmitted rotatively—there are substantially no reciprocating parts and no vibrations, hence no costly foundations and no holding-down bolts are necessary.

Mr. Parsons made very successful use of an electrical governor which was attached to a relay valve working in exactly the same manner as just described. The arrangement of the levers is shown in Fig. 13. Reciprocating motion was

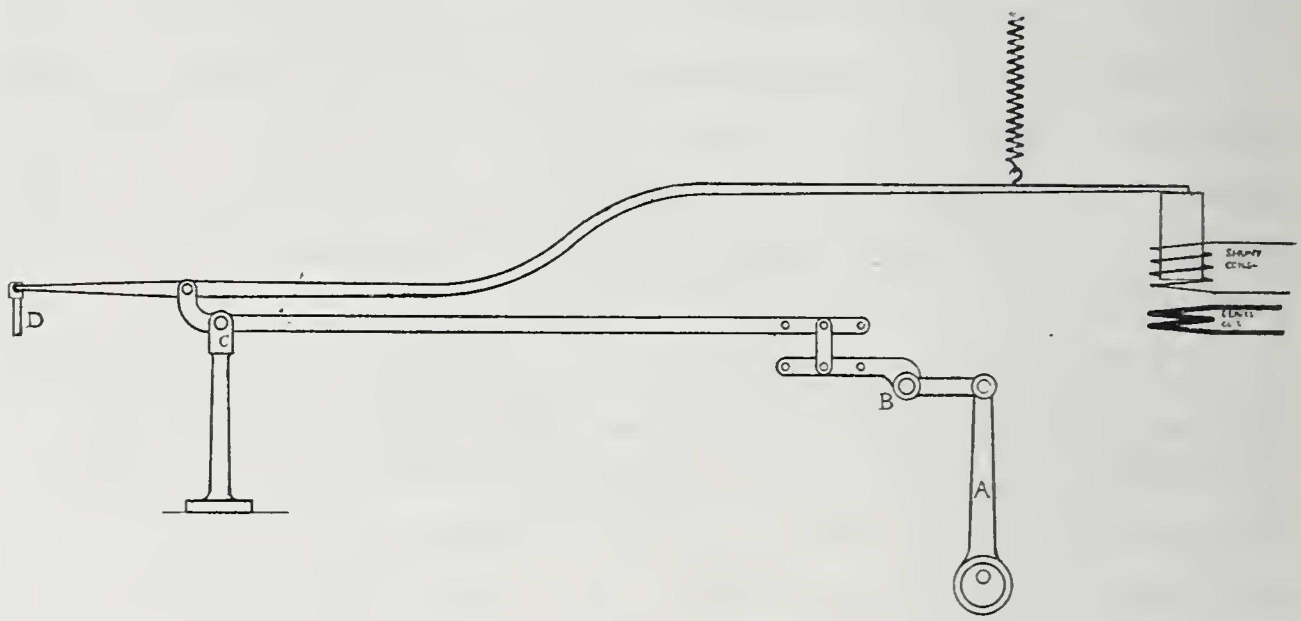


Fig. 13.

given at "A", points "B" and "C" being fixed. On the extreme right is hung, by means of a spring, a core working in a solenoid. When in operation the relay valve "D" oscillates continuously and the core moves a very small amount by reason of its mass. At the same time it is ready to respond to any change of magnetic pull. One great feature of this governor is that the solenoids may be compounded so as to give constant E. M. F. at the terminals of the generator, the turbine running faster at full load than at light load to make up for

copper losses in the armature. The governor may be further over-compounded to give any percentage rise, just the same as an over-compounded generator.

In alternating current work the series coil is obviously separated from the shunt coil. This latter is in shunt with the exciter, and the series coil is usually placed above, having a separate laminated core.

The adjustment of variations of E. M. F. between no load and full load may be conveniently made by changing the amount of iron in the series core.

The essential parts of the turbine are of course the blades and buckets. They are made of hard drawn material. They vary in size from ½ in. to 7 in. according to where they may be used. Every row of these blades has passages of increased area, corresponding with the volume of the steam. This increase of volume is obtained by increasing the heights of the blades, and when these have reached the desired limit, the diameter of the turbine is increased and the steam permitted a higher velocity that enables the blades to recommence another progression.

Considering one barrel of the turbine the fall of pressure, or to be more exact, the coefficients of expansion are the samefor every row.

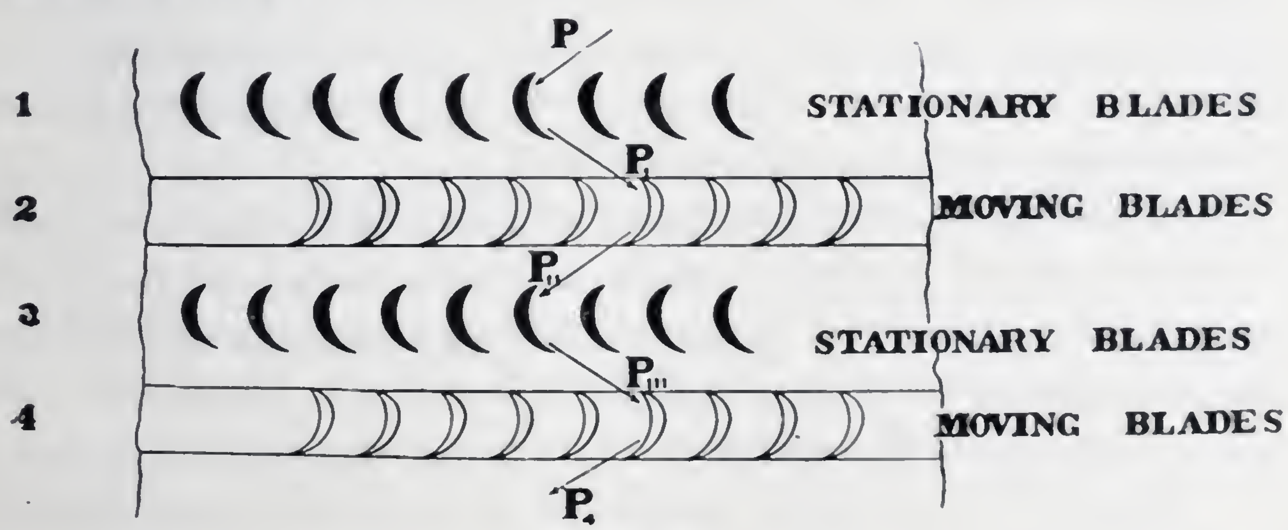


Fig. 15.

Referring to diagram, Fig. 15, the steam at pressure "P" in expanding through row 1 to pressure "P_1" converts its

energy into velocity and impinges upon the moving blades row 2. The steam them performs a second expansion in expanding through row 2, again converting its energy into velocity, but this time the energy of the efflux is to react upon the blades from which the steam issues. The same cycle is repeated in row 3 and row 4 and so on until exhaust pressure is reached. The moving blades therefore receive motion from two causes, the one due to the impact of steam striking them, the other due to the reaction of the steam leaving them, and in this respect is this turbine a combination of Bianca's wheel and Hero's engine.

Many people suppose that these blades wear under the action of steam. Experience shows that they do not. In the case, however, of a nozzle, such as has already been described, in combination with the blades, the result is very different, by reason of the tremendous velocity of the steam. The wear even then is not much when superheated steam is made use of, but with any entrained water the wear is quite rapid. In the Parsons turbine the velocities of steam never exceed 500 to 600 feet per second, and for the most part are considerably less than this.

The blades are secured by calking in the manner shown by the samples. Experiments show that the pull necessary to pull them out is as much as the elastic limit of the material of the blades themselves. The strain to which they are subjected in practice is about $\frac{1}{40}$ of this amount.

It may be observed in some of the smallest samples that you have before you that a blade has been pulled out in order to test the resistance. The pounds pull have been marked on the side and are of figures ranging from 300lbs. to 400lbs In every case the blade stretched considerably before it came out.

Danger of the blades colliding sideways is very remote. The smallest blades have $\frac{1}{8}$ in. clearance sideways and the largest as much as $\frac{1}{2}$ in. These dimensions are far beyond the limits of lateral motion permitted by the balance pistons. Of course accidents *do* happen to the blades, but are generally attributable

to carelessness, such as the machine having been taken apart and in handling, some of the blades damaged, the machine being again assembled without having the damage repaired. The result of this, however, is less serious than would be expected. At the most two or three rows are ripped out. The blades are very tough and the first broken blades close up the passage in the succeeding guide blades and prevent the broken pieces passing and causing more damage.

In the event of such an accident, the damaged blades may be removed and the machine put into service when full power can be developed, but of course at a somewhat less efficiency, according to the number of rows missing. The blades may be permanently repaired in a very short time by chipping out the grooves and inserting new blades. This work can be done wherever the machine may be in service, as no special machine work is necessary. Such accidents, however, are among the improbabilities.

It may be interesting to record the actual pressure exerted on individual blades in a turbine. Take, for example, one of 300 K. W. capacity, to which special reference will be made. There are altogether 31,073 blades in the turbine, of which, 16,095 are moving blades. The pressure that each of them exerts in revolving the shaft varies from .89 to 1.04 ounces.

The steam inlet is always provided with a steam strainer, which is intended to prevent foreign substances from getting into the turbine by means of the steam pipe. Generally such things as nuts, bolts, monkey-wrenches, etc., as have occasionally been known to come through a steam pipe, cause practically no damage because they cannot pass the first row of guide blades. The greatest inconvenience of this nature small pieces of gasket choking up the guide blade passages, which appreciably brings down the power.

As has been already stated, a jet of steam issuing through a properly constructed orifice has as much energy as the same steam performing high ratios of expansion behind a piston. In both cases the work to be theoretically abstracted from a

given weight is the same. However, there are some practical reasons for expecting better results in the case of the turbine.

In the design of a three or four stage compound condensing reciprocating engine, it is found that there is no gain in economy by expanding the steam in the low pressure cylinder beyond a terminal pressure of about 5 or 6 lbs. absolute. To do so means very much increasing the volume of the L. P. cylinder, thus increasing the friction of the engine and the weight of reciprocating parts. Moreover the temperature of saturated steam, as these low pressures are reached, falls off much more rapidly; hence there are greater losses, due to condensation and re-evaporation than would be gained by a more complete expansion. In the steam turbine, no such limits exist. The extra volume of the L. P. end does not add to the friction. The temperature conditions from end to end remain always the same, and hence such losses as condensation and re-evaporation are not in evidence.

Turbines are constructed to utilize the energy of the steam down to the utmost limits. A condensing steam turbine, when in operation, affords a striking example of the conversion of heat into energy. The temperature of the walls of the cylinder at the high pressure end, about 365° F., falls in the distance of three or four feet to a temperature of about 126° at the low pressure end.

The diagram Fig. 16, shows some economy curves developed from tests made on one of the 300 K. W. turbines now in operation at the Westinghouse Air Brake Co.'s works. The results may be summarized as follows:

Full load	16.4	lb. steam	per	E. H. P.	hour.	
$\frac{3}{4}$	17	"	"	"	"	
$\frac{1}{2}$	18.2	"	"	"	"	
$\frac{1}{4}$	22	"	"	"	"	

Running light, 750 lbs. per hour.
Vacuum, 26 to 27″.
Boiler pressure, 125lbs. per square inch
R. P. M., 3,600.

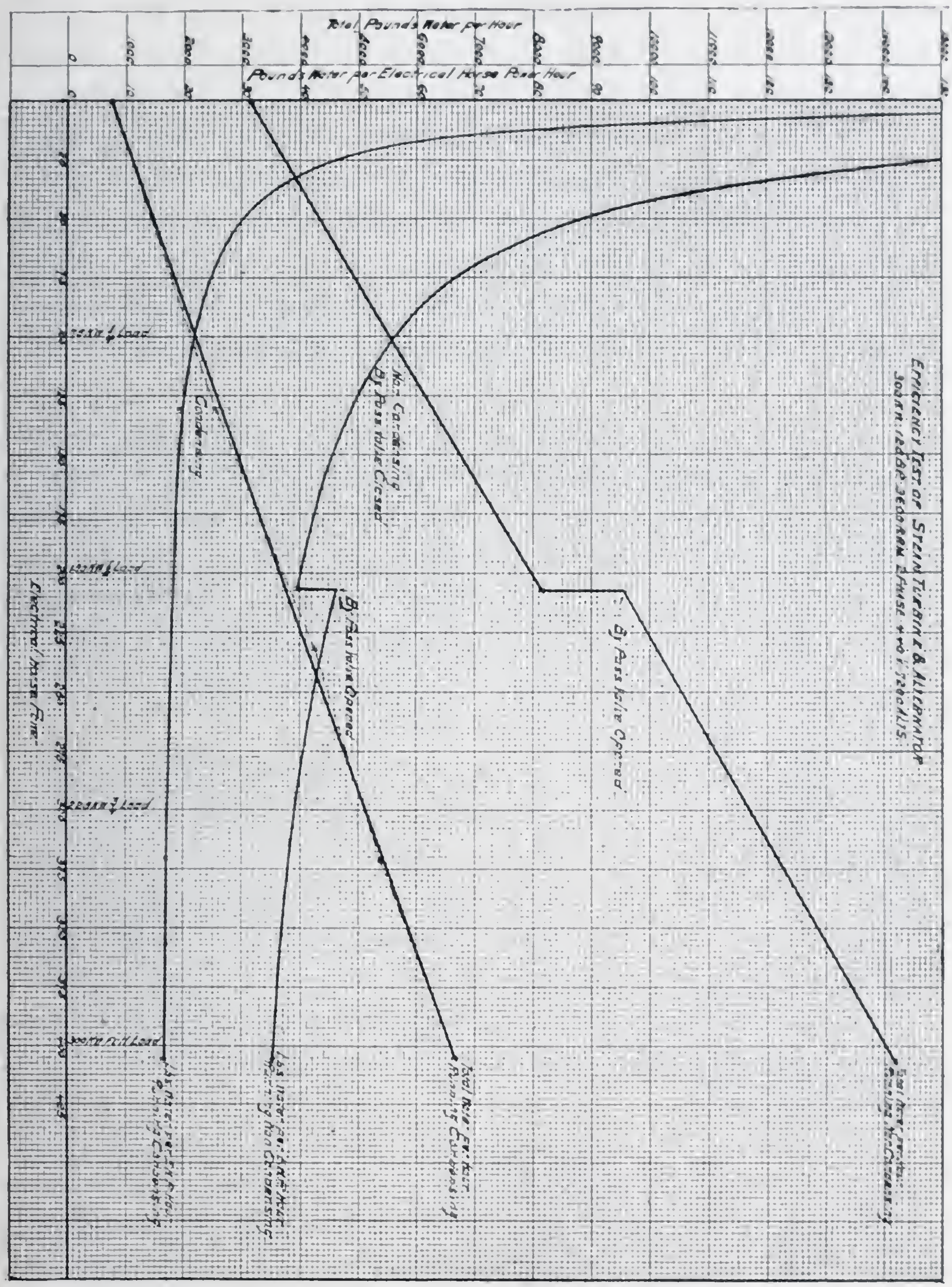


Fig. 16.

The consumption of 16.4 lbs. at full load is in itself remarkable, but such results as at the light loads have never been approached before. It may be said that the consumption at $\frac{1}{2}$ load is only 10 to 12% greater than at full load.

It must not be lost sight of that these results are per electrical horse power. It is usually the custom of engine builders to publish their results per indicated horse power, which means very little to the power user. He is chiefly interested in the economy of steam per unit of power he gets out of his power plant, not the steam per unit of power he has to put into it.

To make a comparison with a reciprocating engine and assume the efficiency of transmission from the steam cylinders to the switch board to be 85%, which is about the very highest attainable, would bring the full load water rate on the turbine just described to 14 lbs. per indicated H. P. The tests were made under ordinary conditions so far as dryness of steam is concerned, the boilers being some distance away, and no allowance made for wetness of steam.

On the curves are shown a set of lines showing the efficiency when running non-condensing. These results are somewhat inferior by reason of this particular turbine being designed essentially for condensing. Nevertheless the results are not so bad as to preclude it being operated under these conditions, should at any time the condenser be out of order.

A turbine designed for running non-condensing gives proportionately as good results as the condensing curves shown on the diagram.

By this set of curves may be observed the function of the by-pass valve, how, when running non-condensing, the by-pass valve remained closed until about half load was reached. Upon being opened the efficiency fell off, as shown, and continued to improve from there on as the load increased. The over-load capacity of the engine is obviously more flexible than that of most engines.

Super-heating may be made use of with considerable gain in economy and without the usual difficulties. There are no internal rubbing surfaces and no packing glands to become injured by the high temperature. 60° to 70° of super-heat improves the economy by some 20%.

In this connection Prof. Thurston has lately recorded some experiments with a de Laval turbine. For every 3° F. of super-heat 1% of gain in economy was attained. With 37° of super-heat the capacity of the turbine was doubled. This gain he attributes almost entirely to the reduction of skin friction.

The practical efficiency of a turbine power plant may be gathered by some tests made by the Westinghouse Air Brake Co. After the plant had been installed some nine months the whole plant was shut down, and the steam engines which had been previously doing the work, were connected up again, put in service and were kept running a week, during which time careful measurements were taken of fuel and water. After this the turbine plant was again put in operation and similar measurements made with the electrical transmission. The saving in coal averaged 35.7% during the day and 36.4% during the night in favor of the turbines. The saving in feed water averaged 29.8% during the day and 41.4% during the night. In round numbers this means a saving of 40,000 lbs. of coal in 24 hours.

The gain is in a great measure due to the economy of the turbines, but also to some extent to the elimination of the condensation in long lengths of steam pipe and to the advantages of electrical transmission.

Figs. 17 and 18 show views of this power plant. In the foreground of one may be seen the 10 H. P. exciter engines and generators, and their size, compared with the 500 H. P. steam turbines. The whole outfit of three turbines and generators, aggregating 1500 H. P., occupies a floor space of 24 feet square, and allows ample room for access to the turbines.

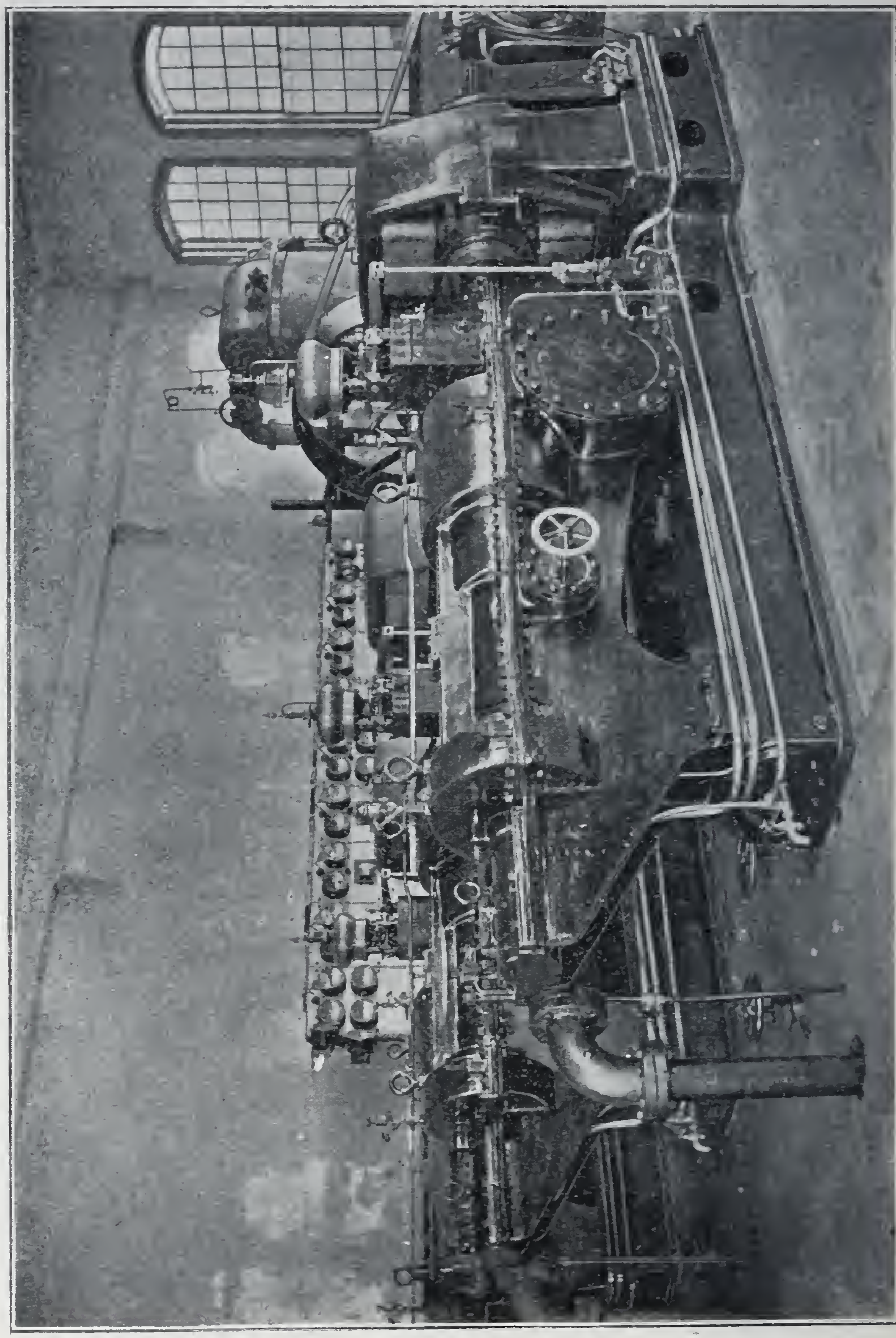


Fig. 17.

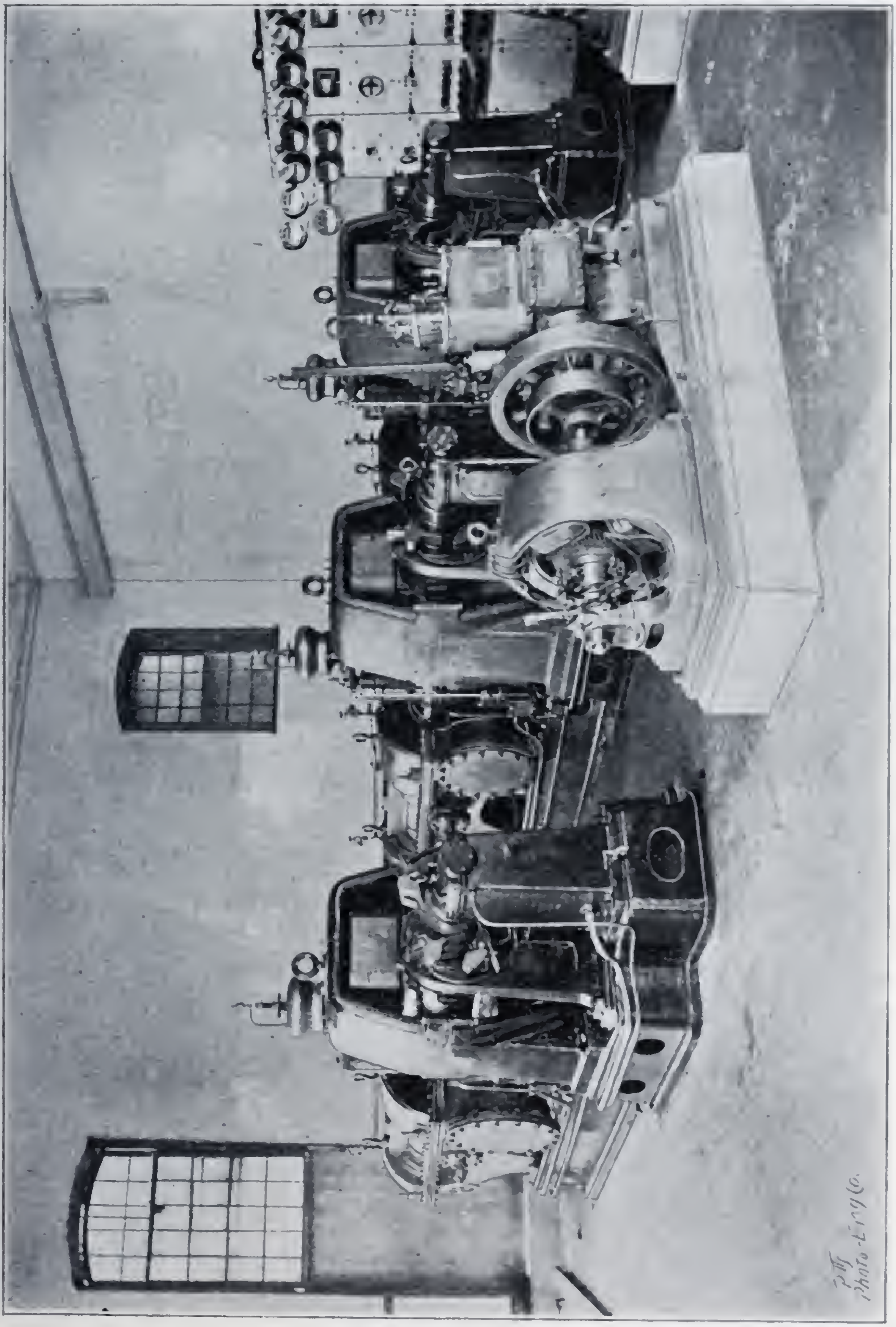


Fig. 18.

The turbine and generator are shown separately on Fig. 19 (frontispiece). The total weight is about 25,000 lbs.: total length 19 ft., and width, 4 ft. 3 in.

Lately a 1000 K. W. outfit has been built by C. A. Parsons & Co. for the Elberfeld Corporation in Germany.

At 1,200 K. W., 130 lb. boiler pressure, 18° F. of superheat, the turbine driving its own air pump, &c., an electrical horse power was produced for 14,025 lbs. This is probably the highest economy ever attained in any steam engine.

Fig. 20 shows the complete revolving part of a 3,000 H. P. turbine. Its weight is 28,000 lbs., length over all 19 ft. 8 in., and 12 ft. 3 in. between bearings; the largest diameter, 6 feet.

The turbine, of which this forms a part, is shown on Fig. 21, and is being set up in the power house of the Hartford Electric Light Co. It is direct connected to a 1,500 K. W. generator; the total outfit having the following dimensions: 33 ft. 3 in. long and 8 ft. 9 in. wide, 175,000 lbs. total weight, including generator. This is the largest steam turbine in one integral part ever built.

As there are no rubbing surfaces in the turbine, no internal lubrication is necessary. This enables surface condensers to be employed and the condensed water used for boiler feed without fear of getting grease into the boilers.

The turbine is entirely automatic in all its functions, and requires remarkably little attention. The only real working part is the spindle revolving in its bearings. These bearings are found to wear but little, if at all, so the cost of repairs and renewals is very small.

In 1897 the Newcastle & District Electric Lighting Co. published their costs in this regard. The power house contained 11 turbines of 75 to 150 K. W. each. The cost for repairs and renewals amounted to $\frac{26}{100}$ cent per K. W. per annum, and included all repairs to boilers, turbines, condensers, pumps, generators, cables, fittings, etc.

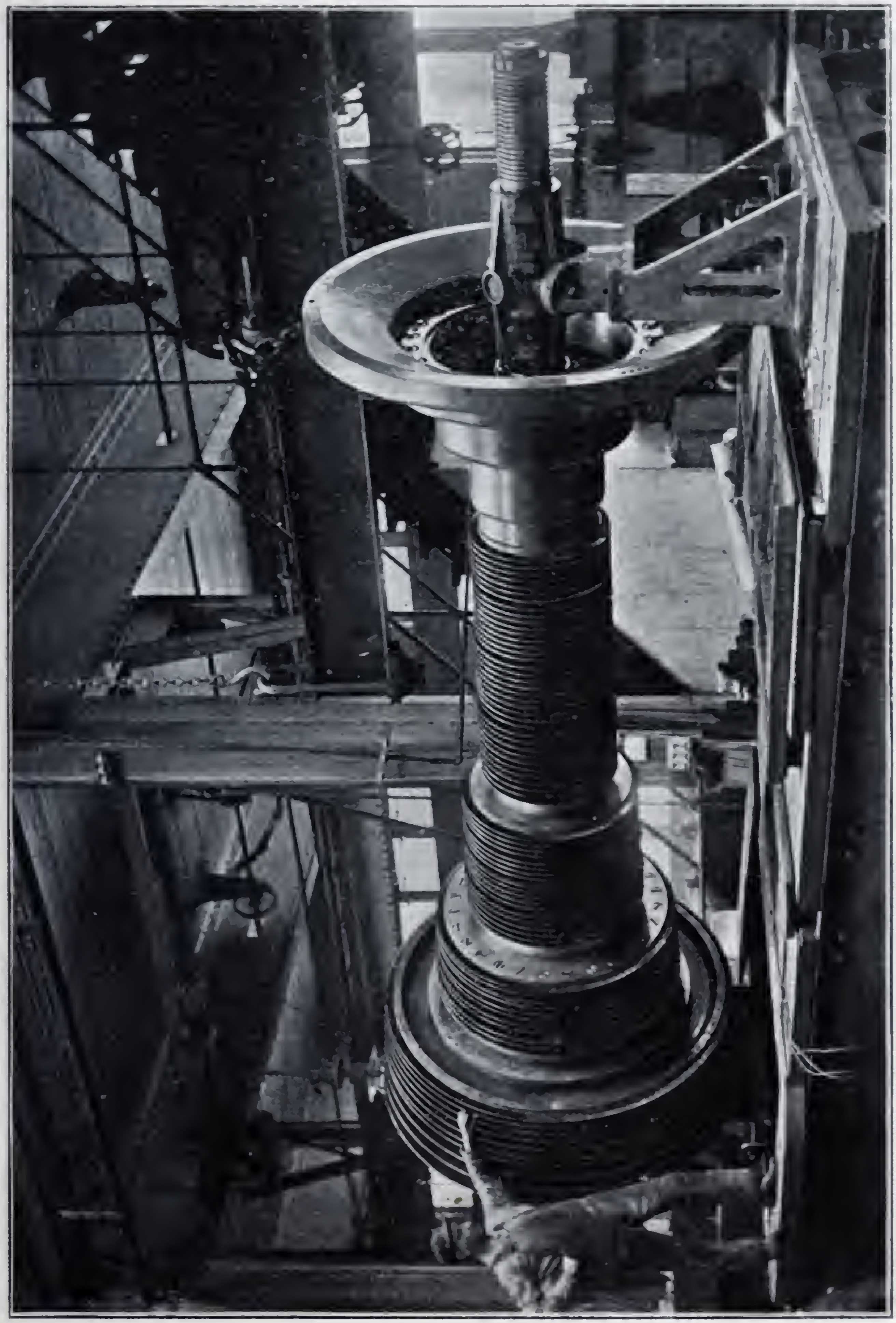


Fig. 20.

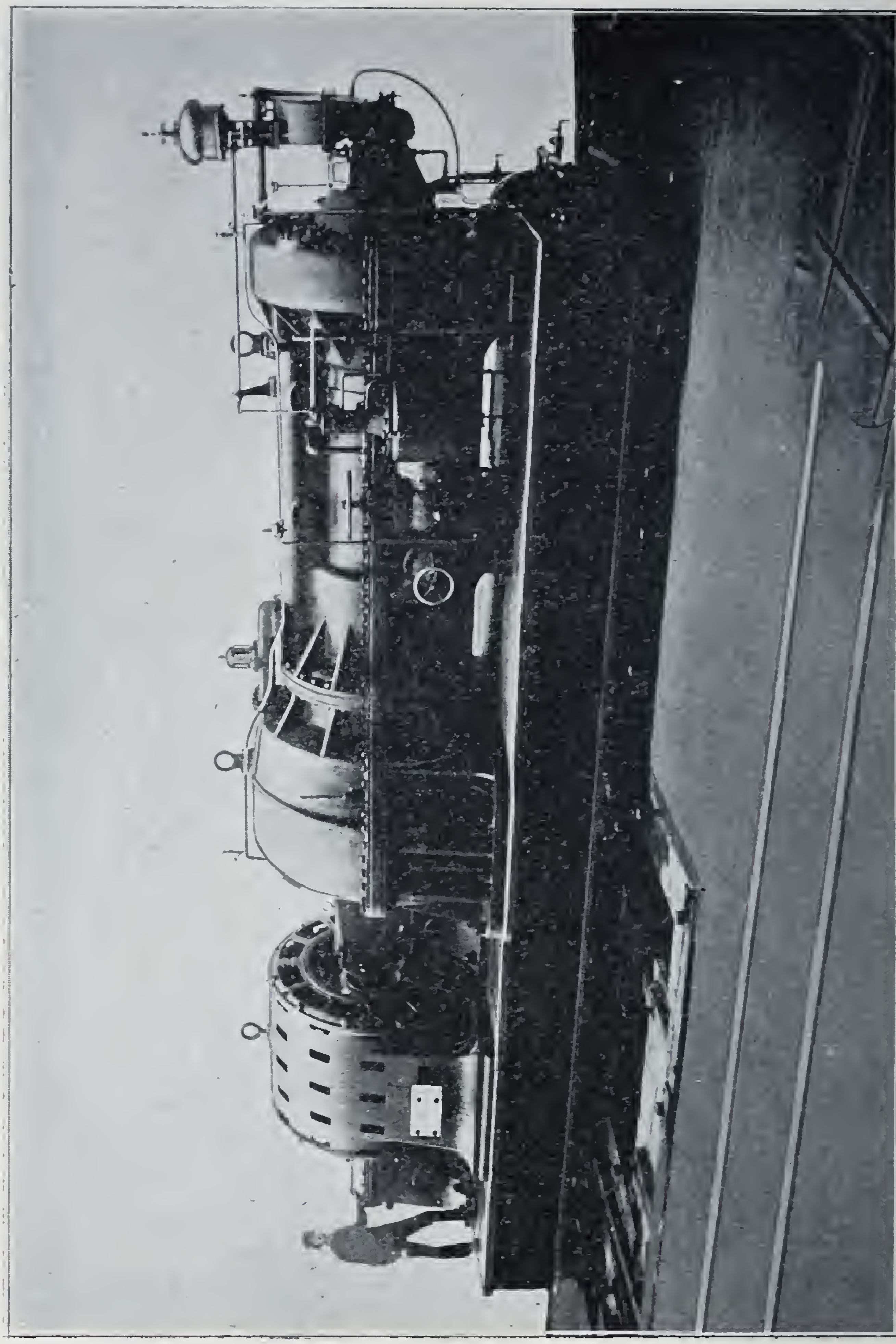


Fig. 21.

By reason of the turbine making use of the last available expansion of the steam there is considerable advantage in employing the highest vacuum. For instance, considering the 300 K. W. turbines described, and assuming the steam consumption with 27 in. vacuum to be 16.35 lb. per electrical horse power hour, it may be reasoned upon a thermodynamic basis that with the same machine designed for 25 in. vacuum the consumption would be 18 lb. per E. H. P. hour.

On the other hand by designing the same turbine to suit an exhaust pressure of $\frac{1}{30}$ of an atmosphere, or say 29″ vacuum, the consumption would come down to 14.12 lb. per E. H. P. hour.

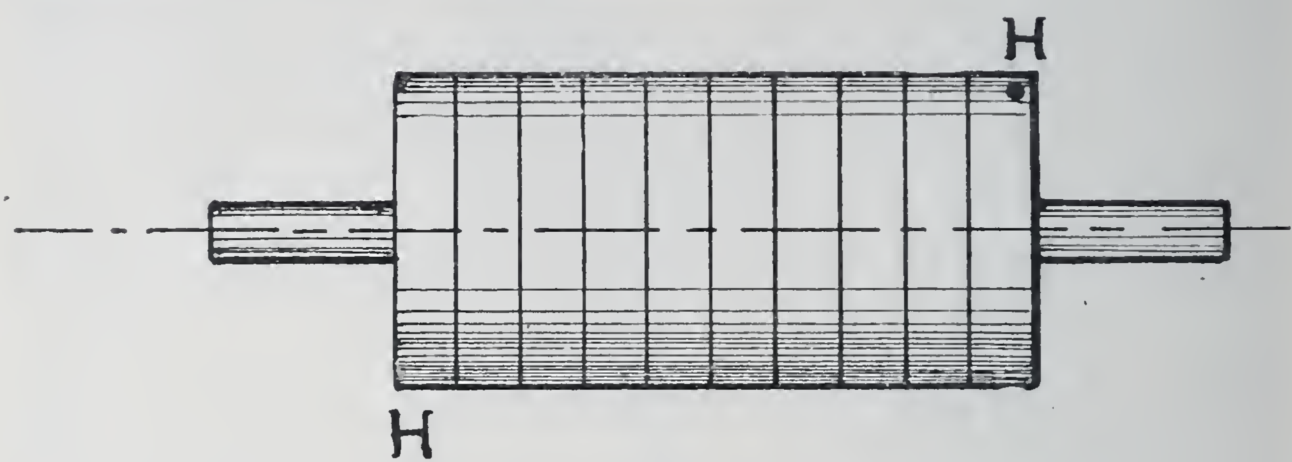
The applications of steam turbines are perhaps not so universal as ordinary steam engines. They are pre-eminently suitable for driving electrical machinery, particularly alternating current dynamos. Some difficulties are, however, experienced with the commutation of continuous current generators of fairly large powers.

There is nothing remarkable in the design of generators for this purpose, except that modification necessitated by the high speed. For this reason they are remarkable for their small weight and dimensions, and the absence of crowded pole pieces.

Builders of electrical machinery have for some years been working in the direction of reducing speeds from the old belt driven rigs to admit of direct connection to slow going reciprocating engines. The condition for steam turbines is, however, a step in the reverse direction. Turbines have been used with good success in England for driving fans and blowers.

Although the type of bearing employed is capable of successfully dealing with about any reasonable error in balance, at the same time it is very essential that the revolving parts be very accurately balanced, in order that the collector rings and commutators may run true, and that the clearance between the tips of blades and walls of the turbine cylinder may be maintained as fine as possible, so that balancing forms quite an

important stage of the construction and has many interesting features. The usual method of balancing, which consists of rolling the piece on some ways and thus locating the heavy side, is sufficiently accurate for ordinary slow speed work, but no degree of real accuracy can be attained.



Attempting to balance a body, such as the above, by such methods, might result in a heavy spot at two opposite sides and two opposite ends, as at "H" and "H," which would be anything but a condition of good running balance. It is, therefore, found desirable to split this up into comparatively narrow rings and balance each separately, when the above error would become negligible. For balancing such rings, The Westinghouse Machine Co. have devised a machine which performs the work with remarkable accuracy. It is shown in Fig. 22, which shows a ring in place on the turntable. The turntable is pivoted, on a beam which is in turn hung on two knife edges. Below the turntable is rigidly attached an adjustable counterweight. The turntable of course is free to turn independently of all this. Means are provided to slide the whole turntable and counterweight in the beam and in a direction at right angles to the line of the knife edges.

The counterweight is adjusted to bring the combined center of gravity in a plane close to the knife edges. Then by sliding the mass in the beam the table may be made to rest horizontally. Then by giving the turntable $\frac{1}{2}$ revolution the table will fall over by twice the amount it is out of balance.

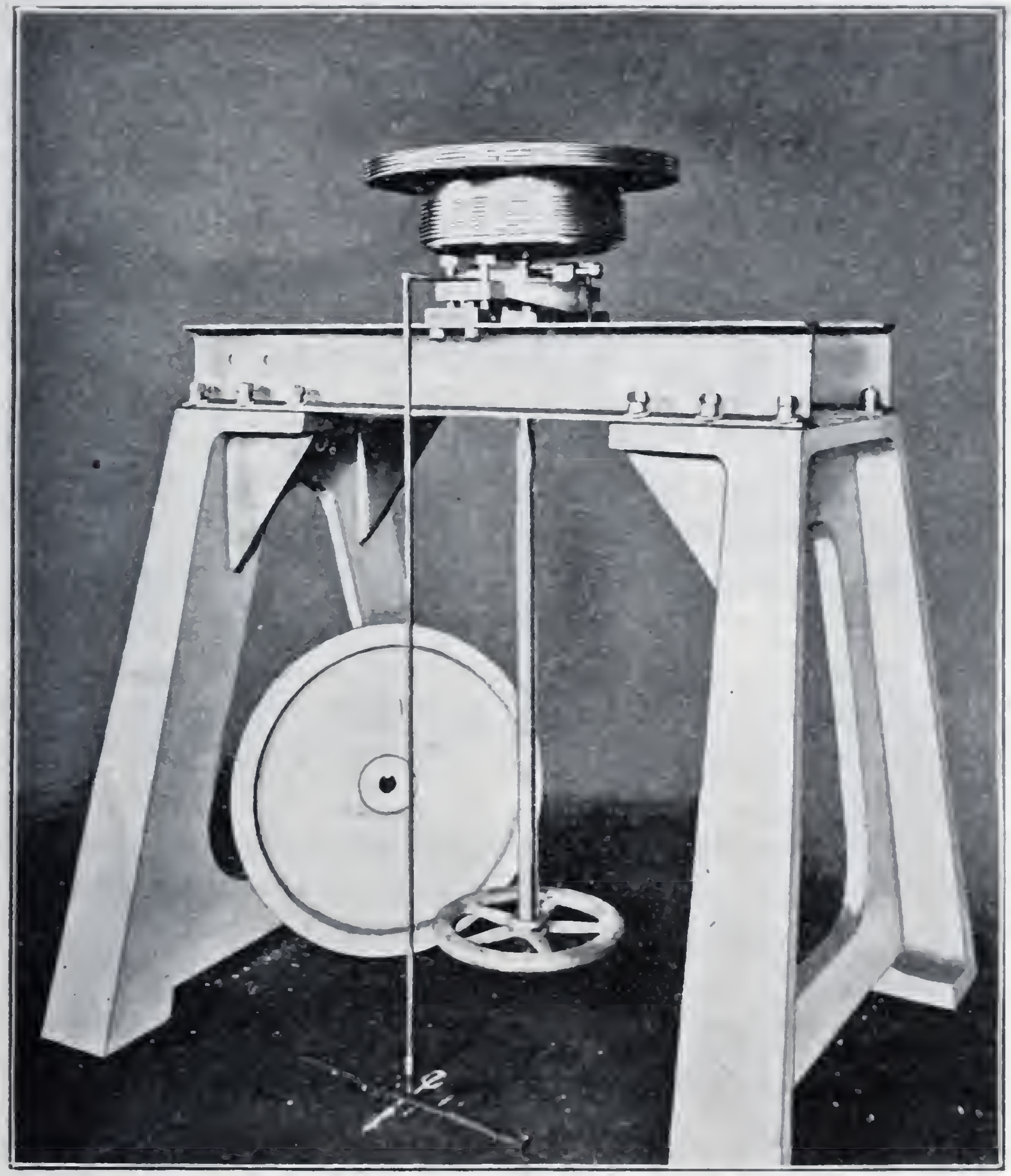


Fig. 22.

Readings are taken in two opposite directions and the exact location and amount of the error may be immediately figured.

Balancing by this method may be done very rapidly and with surprising accuracy. A ring weighing 6,000 lbs. has been balanced within 2 ounces, and rings weighing 200 or 300 lbs. within $\frac{1}{8}$ of an ounce.

In the case, however, of the revolving parts of electric generators the final winding, etc., is liable to throw it out of balance, and then there is no alternative but to balance it in its entirety. The shape is generally of the nature of a long cylinder with a journal at both ends. The only way then to do this balancing is to deliberately mount it on bearings which are preferably set on springs and running it up to speed by belt or any available means. While running it is marked with a colored pencil at different points, which serve to indicate where to add weight.

A small body revolving at 5,000 or more R. P. M.—the light side is always the side that comes outward, so that weight should be added just where the marks come. In some cases the marks are opposite at each end, when weight needs to be added on one side at one end, and on the other side at the other end.

These facts show that when the high speeds are reached the body ceases to revolve on the geometric axis and takes the axis of gravity.

On its way up to speed there is generally some point at which there is considerable vibration. This is termed the critical speed, and seems to come at the time the body is changing its axis of revolution. These critical speeds become lower as the bodies are heavier and of greater radius. In the cases of heavier and bigger bodies, which also would have a lower rotative speed, the marks do not come just on the light side. They may come sometimes as much as 90° ahead of the light side. The exact angle can only be found by experiment, and at best this is only a cut and try method. With experience, however, work may be put in very accurate balance.

The application lately of steam turbines to marine propulsion is well known. Some particulars of the vessels equipped may be interesting.

The first vessel, named the Turbinia, was built with a view of exploring the possibilities of turbines for this purpose. It

was therefore built as small as possible, and at the same time not so small as to preclude the attainment of high speed should the experiments turn out a success. The dimensions selected therefore were 100 feet long, 9 feet beam, 3 feet draught and 44 tons displacement. It will be noted that the ratio of beam to length is unusually small—$\frac{9}{100}$, while $\frac{10}{100}$ or $\frac{11}{100}$ is the more usual practice for this class of boat.

To begin with, the boat was fitted with one single turbine and propeller. The result was disappointing, the chief trouble being due to cavitations in the propeller, resulting in excessive slip. This was verified by experiments in a tank of water subjected to vacuum. The appearance of the action of the propeller in the water was observed by looking through a slot in a disc which was made to revolve in synchroism with the propeller under observation.

It was then considered necessary to make several changes. New engines were built in three sections, the steam expanding through them in series, each section driving an independent shaft and each shaft three propellers. Very soon $32\frac{3}{4}$ knots were attained, and eventually $34\frac{1}{2}$ knots at the naval review at Spithead in 1897. About 2300 I. H. P. were developed. The boiler, a Yarrow type with small tubes, had 1100 square feet heating surface and an evaporation of about 28 lb. of water per square foot of heating surface at $34\frac{1}{2}$ knots speed. About 600 H. P. were developed per ton of machinery and 50 H. P. per ton of total weight of vessel in full equipment. These successes resulted in a contract with the British Admiralty for a torpedo boat destroyer named the Viper. The dimensions were the same as the 30 knot destroyers of her class, 210 feet long, 21 feet beam and 350 tons displacement. The engines consisted of two independent sets, each consisting of one high pressure turbine driving a shaft, and one low pressure turbine driving its shaft. On the same shaft as the low pressure was permanently connected a small turbine for reversing purposes. When running ahead the reversing turbine was in connection with the

condenser, so that the frictional losses due to this turbine running idle were very small. The same fact applies to the go-ahead turbines when running astern.

There were therefore four propeller shafts, each fitted with two propellers; the one ahead having a slightly lesser pitch than the after ones.

The Yarrow type boilers have 15,000 sq. feet heating surface; grate surface 272 sq. feet; condensers have 8,000 sq. ft. surface. The speed attained was 35 knots to begin with, and later 36.858 knots were reached.

It is generally conceded by engineers that but little more may be anticipated in the development of the reciprocating engine. Any improvement that we can imagine would not very materially improve its efficiency as a heat engine. On the other hand, the turbine is capable of development in many ways, particularly in the use of super-heated steam, to a degree hitherto prohibitive, so that the day may not be very far distant when the turbine will replace the reciprocating steam engine for most purposes.

In conclusion, I must express my thanks for your kind attention and my indebtedness to the Westinghouse Machine Co., for their permission to read this paper and for the use of the various drawings and photographs, etc., that we have had before us.

DISCUSSION.

Mr. Bole—Gentlemen, we have listened to a very interesting paper on a very interesting subject. I can say that Mr. Hodgkinson has been connected with the building of turbine engines for a great many years, and is one of the few men who thoroughly understand the subject. He came over from the Parsons' Works in England to superintend the building of the Westinghouse turbines, which they were granted a license to construct. He has devoted many years of very hard work to the subject, and I hope you have all enjoyed the paper.

A Member—I would like to ask the diameter of the screw used on boats mentioned.

Mr. Hodgkinson—On the boat they experimented with the go-ahead one was about 18″; the other 3 feet.

A Member—What was the revolution per minute?

Mr. Hodgkinson—They tried different speeds in experimenting, and got up to 2,000. I don't know the exact revolution they use at the present time.

Mr. Chester—As shown on Fig. 8, how do they prevent the steam passing backward. It has got to have some clearance, has it not, in order to turn?

Mr. Hodgkinson—There is, undoubtedly, some leakage, but as I stated, the leakage is small in view of the results we get.

Mr. Chester—What becomes of the leakage?

Mr. Hodgkinson—It goes into the exhaust pipe. Suppose that piston C is leaking more so than the others, therefore more steam will pass through there, and the steam will leak up into F and do work. Of course there is generally some leakage which goes into the exhaust pipe.

Mr. Chester—It is stated that you require 14 lbs. of steam per electrical horse power. In the pumping engine they have got it down below 11 lbs. per pump horse power. How does that compare with electrical horse power?

Mr. Hodgkinson—I don't know what efficiency of transmission is used in a pumping plant. They must have had super-heated steam.

Mr. Chester—I think the average was 80 per cent. You will find in a paper read by Mr. G. H. Barrus, before the New England Water Works Association, December 14, 1898, he averages up the efficiency of five different engines and gets about 80 per cent. Some of them had super-heated steam and some did not. One or two had super-heat. The 80 per cent. efficiency obtained as referred to the low pressure cylinder or, *mean effective pressure referred to the low pressure cylin-*

der divided by *the theoretically mean effective pressure referred to the pressure near the throttle valve and the ratio of expansion at the same point.* In the same paper, the per cent. of the friction of these engines varies from five to ten per cent. I would, however, cite the recent test of the engine built by the Allis people for the City of Boston, a duty of 178.6 millions foot pounds was obtained for each 1,000 pounds of dry steam consumed, no super-heat. This, as you know, is equivelent to about 11.2 pounds of steam per pump horse power.

Mr. Hodgkinson—Of course super-heat adds very much to the efficiency. I think a first class water plant should have more than 80 per cent.

Mr. Bole—It must be remembered that this leakage is charged up against the engine.

Mr. Hodgkinson—In this instance as soon as the steam is consumed it is charged against the horse power produced.

Mr. Chester—I did not really see how it could be accounted for, but I see now that it would do some work passing back.

Mr. Albree—Does the machine run noiselessly?

Mr. Hodgkinson—There is a certain amount of humming, but it is so slight that a wooden partition would generally keep it out. At 1,500 revolutions per minute it runs perfectly noiselessly. Of course the generator makes some noise; otherwise it is very silent.

Mr. Flanagan—I would like to call the attention of the members to the remarkably clear and lucid explanations of a machine with which most of us are anything but familiar. I think all will agree with me when I say that Mr. Hodgkinson has put more facts into a small number of words than are usually found in scientific and technical papers. I have tried to think up a question to ask him which he has not already answered, and the only one I can think of is, What kind of material are the blades made of? Those passed around are apparently bronze. I would like to ask if other materials

would be affected by the steam, whether this is a subject that has been gone into much, and whether there is one metal that is preferred over another?

Mr. Hodgkinson—Hard drawn bronze metal is preferred because it does not corrode and by reason of its great strength. You will notice how very rigid the blades are in the specimens passed around. Such blades would be used in a 500 horse power turbine.

Mr. Bole—Mr. Hodgkinson has called attention to the fact that the pressure is exceedingly small on each blade. It is expressed in ounces. The greatest tax of strength of the blade is that imposed by centrifugal force.

A Member—I would like to ask the clearance between the blades.

Mr. Hodgkinson—It is desirable that it should be as fine as possible, about .025 in. clearance. We also have them as much as .050 in. The larger the blade the more leeway you must allow. As stated before, the blades receive motion from two causes – one from the steam striking them and one from the steam leaving them.

Mr. Stewart—I would like to ask the price of these turbines as compared with a regular steam engine of the same power.

Mr. Hodgkinson—I would say, generally, that a steam turbine generator, with all the outfit, can be sold at the same price as a Westinghouse compound engine and generator outfit.

Mr. Bole—In other words a steam turbine generator can be sold, at about the same price as any other machine of equally high efficiency. The price of a turbine engine and generator can be said to be about on a par with a high-class compound triple expansion engine.

A Member—Stress has been laid on the turbine being suitable for driving an alternating generator. I want to ask the difference.

Mr. Hodgkinson—There is always a difficulty in driving

an alternating generator in multiple. The difficulty is in the fact that it is impossible to give a perfectly uniform rotation. That is, the revolving shaft will go a little quicker at one point than at another during one revolution. That would not matter much in a not direct current but in an alternating. The machine would "buck" and would get out of step—but in the turbine there is substantially no such variation.

Mr. Bole—That is of the utmost importance in the successful running of very large electrical plants. We all appreciate the difficulty in driving several engines in a factory by means of tooth gears on account of back lash and diference in their velocity. The ordinary engine revolves not in a perfectly uniform manner, but in fits and starts. The fly-wheel is the means usually employed to keep it at a uniform velocity. By this means the engine does not start and stop at every revolution, but keeps a sustained rotation in one direction only. Now-a-days power stations are assuming sizes that a few years ago we never dreamed of. The application of the turbine is very hopeful. Fly wheels are now being built for large engines to apply to ordinary engines service, weighing as much as 300,000 to 350,000 lbs. for single engines.

The difficulty of driving alternating generators in multiples might be explained by Mr. Scott.

Mr. Scott—The difficulty in driving alternating current generators in multiple does not apparently lie in the alternator, but in the engine, and the difficulty of securing uniform angular velocity which Mr. Hodgkinson has just spoken of in the comparison of the turbine and the engine, is rather a difficulty in the design to be taken up at the beginning and arranged for once for all, rather than a difficulty in operation. That is, the engine must be designed with the fly wheel in proportioned and the governor adjusted so as to meet certain conditions, and if these things have been done it is usually a comparatively simple matter to operate in multiple. There

are many stations operating in multiple now, and I don't recall any station which it is desired to operate in multiple and in which reasonable provision has been made, in which the operation is not carried on. That is, operation with engines of the present class is a thoroughly practical matter.

You notice in the figures that were shown that the alternator is not of the usual form as there, but two poles. In Fig. 19 the alternator shown gives 7,200 alternations per minute. Two poles and 3,600 revolutions give that product. To give the same number of alternations an alternator run at 100 revolutions would require 72 poles, and it run at a lower speed would require still more poles. It would be impossible to run an alternator at more than 3,600 revolutions and obtain 7,200 alternations, so that in this way the speeds which can be used for a given number of alternations are definitely fixed. The number of alternations, 7,200, is the one in common commercial use. In this case the turbine speeds would have to be 3,600, 1,800, 1,200 or less; so that these interesting limitations are brought on by rate of alternations of the alternators, and the fact that the alternator must have an even number of poles.

A MEMBER—Can you give the number of these machines in use in this country?

MR. HODGKINSON—There are not many in use in this country, probably seven or eight. There are many being built in Europe. They vary in size. The last one built by the Westinghouse Machine Co. has a capacity of 3,000 horse power.

MR. BOLE—The demand upon the engine builder in this matter of speed and velocity might be expressed in a homely way in some such fashion as this: that engines of large size and power may have fly wheels in diameter 28 ft. The two sets of engines intended to produce alternating currents in multiple must be possessed of such qualities that if two fly-wheels were marked at given points, those two points would

never deflect from each other, say an inch. If you imagine a 28 ft. fly-wheel running absolutely uniformly and running alongside of it one of the same diameter, each marked, these two marks must remain in the same relation to each other. So that to design an engine which will transmit 500 H.P. one minute, 1,000 the next, and 3,000 a few minutes later, and keep that fly-wheel running in the same uniformity is one of the tasks that is imposed upon engine builders.

A MEMBER—Mr. Scott has called attention to the high speed and I presume that we are not to look forward to any material reduction of speed in that class of machines.

MR. HODGKINSON—In case of the turbine, of course we are working always in the direction of reducing these speeds, but have not succeeded very much yet.

MR. BOLE—A slower speed turbine would involve a larger diameter turbine, which would increase the cost of the turbine.

A vote of thanks was tendered Mr. Hodgkinson by the Society for his very interesting paper.

On motion the Society adjourned at 10.30.

REGINALD A. FESSENDEN,
Secretary.

MEETING OF THE CHEMICAL SECTION.

PITTSBURGH, PA., November 22, 1900.

The regular monthly meeting of the Chemical Section was held at 410 Penn Avenue.

Meeting called to order by the Vice Chairman, Mr. A. G. McKenna.

The minutes of the previous meeting were read and approved.

It was moved and seconded that the Chairman and Secretary be instructed to request The Engineers' Society to have the Chemical Journals now being subscribed for, bound.

Dr. Stahl then read his paper on "Methods of Analysis used in Acid Works."

After discussion the meeting adjourned at 10.30 P. M.

GEO. O. LOEFFLER.
Secretary C. S.

ARSENIC IN BRIMSTONE.

Sampling:—Portions of about 10 lbs. each are taken from the car, while unloading, until about 150 to 200 lbs. have been secured. The whole is then broken to pieces about 1 foot through, then divided into two unequal parts by taking one small shovel full and placing it on an iron plate and then taking four shovelsfull and placing them in a wheelbarrow and repeating this till all is divided.

The small pile on the iron plate, being one-fifth of the original sample, is then broken to pieces about $\frac{1}{4}''$ through, mixed thoroughly, and one-fifth of it obtained, as described above and broken so as to pass through a screen of six meshes to the lineal inch. The screened brimstone is well mixed and about 20 grammes quartered out as described, and ground in an iron mortar so as to pass through a 100 mesh sieve. This portion is used for analysis.

In sampling piles, portions of about ten pounds each, are taken at distances of about three feet around the base of the pile.

Then starting about two feet from the base, a second lot is taken in the same way and so on until the top is reached. The various portions are then mixed and broken as for samples from cars.

Method of Analysis:—100 grammes are treated with carbon disulphide until sulphur is dissolved. The solution is filtered and the residue washed with CS_2, then extracted with dilute ammonia, filtered and the filtrate concentrated.

The ammonical solution is acidulated with hydrochloric acid, H_2S water added and the solution filtered through a small filter.

The As_2S_3 on the filter is washed thoroughly, dissolved in ammonia and the filter washed. The solution of As_2S_3 in ammonia and the washings are caught in a platinum crucible, the water evaporated on the water-bath, the residue dried at 110°C and weighed.

SODA ASH.

Samples are taken from one-tenth the number of bags of a shipment, with an iron thief, mixed thoroughly and passed through a sieve of 20 meshes to the inch.

METHOD OF ANALYSIS.

1. *Moisture:*—Weigh 5.0 gm. into a platinum crucible, heat to dull redness over Bunsen burner for 15 minutes, cool in dessicator and weigh.

2. *Insoluble:*—25 gms. are weighed into a 300 c.c. beaker, 200 c.c. boiling water added and the solution boiled for 15 minutes, then filtered through an 11 cm. filter into a 500 c.c. graduated flask, washed with hot water and filtrate and washings, when cool, made up to 500 c.c.

The residue on the filter is dried, and separated as thoroughly as possible from the paper. The latter burned in a

platinum crucible, after which the residue is added and heated to dull redness.

About two gm. ammonium carbonate in lumps are then dropped into the crucible, moistened with a few drops of water, dried on water-bath and heated to dull redness, cooled and weighed.

3. *Sodium Chloride:*—50 c.c. from 500 c.c. flask is acidulated with nitric acid and titrated hot with deci-normal silver nitrate solution.

4. *Sodium Sulphate*:—To 50 c.c. in a 200 c.c. beaker a slight excess of hydrochloric acid is added, the solution heated to boiling and 5 c.c. of a 10% solution of barium chloride added. The precipitate is allowed to settle, filtered through a 7 cm. filter, washed, ignited in platinum and weighed.

5. *Sodium Carbonate:*—Measure 50 c.c. from 500 c.c. flask into a 200 c.c. beaker and add 50 c.c. normal hydrochloric acid. Determine the excess of hydrochloric acid used, by means of normal soda solution using methylorange as indicator.

MURIATIC ACID.

Samples are taken out of five carboys from each lot of about 150 carboys. The strength of each sample is determined with a hydrometer and the average strength of the five taken as representing the lot.

METHOD OF ANALYSIS.

1. *Sulphuric Acid:*—Mix the five samples, and run 50 c.c. into a platinum dish. Place dish on water-bath and evaporate till all muriatic acid is driven off. The sulphuric acid remaining is titrated with normal soda.

2. *Arsenic:*—10 c.c. diluted with 10 c.c. water is put into a small, narrow beaker or wide test tube and strong hydrogen sulphide water poured in gently so that the liquids do not mix. If any arsenic is present it will form a yellow ring at the junction of the two liquids in the course of an hour. If arsenic is found by the preliminary test, dilute 200 c.c. acid

with 200 c.c. water, heat gently, but not to boiling, and conduct hydrogen sulphide gas through the liquid till the arsenic is all precipitated. Allow the precipitate to settle, filter through a 7 cm. filter and wash free from acid. Dissolve the arsenious sulphide on the filter with a little ammonia and wash into a 150 c.c. beaker. Make acid, with muriatic acid, pass hydrogen suphide gas till the arsenic is thrown down and filter through a 7 cm. filter. Dissolve again in ammonia and wash into a weighed platinum crucible. Evaporate water on water-bath and then dry in air bath at 110°C. Cool and weigh as arsenious sulphide.

ARSENIOUS ACID.

Samples are taken from five to ten kegs, with an iron thief made in the shape of a gutter 18 inches long and $\frac{3}{4}$ inch wide. The samples are mixed thoroughly and sieved to separate wood chips, etc.

METHOD OF ANALYSIS.

1. *Arsenious Acid:*—Weigh 2.5 gms. into a 500 c.c. graduated flask, add 10 gms. sodium bi-carbonate and 100 c.c. water. Put a small funnel in mouth of flask to prevent loss by spurting, and boil gently for ten minutes. Then add 5 grammes more bi-carbonate, rinse down sides of flask with about 25 c.c. water, and boil till all arsenious acid is in solution, cool, fill up to the mark.

Run the sodium arsenite solution from a burette into 25 c.c. $\frac{1}{10}$ normal iodine solution contained in an 8 oz. beaker, until the solution is only a light yellow. Then add starch paste, and add the arsenite solution drop by drop until the blue color disappears.

The arsenious acid is calculated from the number of c.c. of arsenite used. 25 c.c. $\frac{1}{10}$ normal iodine equals .12375 gms. arsenious acid.

2. *Non-volatile Matter:*—Weigh 5.0 gms. in a platinum dish and heat over a small flame until all arsenious acid is driven off. Cool in dissicator and weigh.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and tenth monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's House, 410 Penn Ave., Pittsburg, Pa., Tuesday evening, Dec. 18, 1900, the President, W. A. Bole, being in the chair, and seventy-seven members and visitors being present. The meeting was called to order at 8:35 o'clock. The minutes of the preceding meeting were read and approved.

For the Board of Direction, the following applicants were reported as passed, and to be voted for at the next regular meeting:

HORACE S. CLARK, -	Engineer, With Westinghouse Air Brake Co., Wilmerding, Pa.
ALEX. COULTER, -	Superintendent, Salem Coal Co., Greensburg, Pa.,
BARCLAY W. EVERSON, -	Sales Agent, Baldwin Locomotive Works, Phila., Pa., German National Bank Bldg., Pittsburg, Pa.
JAMES SMITH HARING, -	Civil Engineer, Crafton, Pa.,
GEO. WEYMOUTH HUTCHINSON,-	Mining Engineer, With Coulter & Huff Interests, Greensburg, Pa.
GUY ROCHE JOHNSON, -	Superintendent, Blast Furnaces of Duquesne Works, Carnegie Steel Co, Duquesne, Pa.
THOMAS H. JONES, -	Superintendent, Jones & Laughlins Soho Mill, Pittsburg, Pa.
JESSE D. LYONS, -	Gas Motor Engineer and Salesman, 401 Chronicle Telegraph Bldg., Pbg., Pa.

EUGENE L. MESSLER -	General Superintendent, Jones and Laughlins Eliza Furnaces & Coke Ovens, Pittsburg, Pa.
J. WEIDMAN MURRAY, -	Resident Manager, The Edward P. Allis Co., German National Bank Bldg., Pittsburg, Pa.
HUGH McCULLEY, -	Superintendent, Jones & Laughlins Machine Shop, No. 50 32nd St., S. S., Pittsburg, Pa.
DANA STEWART ROLFE, -	Assistant, To Gen. Mgr. Jones & Laughlins, Ltd., Steel Works Dept., Homestead, Pa.
R. I. TODD, - - -	With Carnegie Steel Co., Duquesne, Pa.
FRANCIS H. TREAT -	General Superintendent, Jones & Laughlins, Ltd., 302 Fairmont Ave., Pittsburg, Pa.
SAMUEL MONT'Y KINTNER, -	Prof Electrical Engineering, Western University of Penna., Allegheny, Pa.
THOMAS STEEL PERKINS, -	With Westinghouse Elec. & Mfg. Co., Idlewood, Pa.
RICHARD ANDREW L. SNYDER, -	Chief Tester, For C. D. & P. Tel. Co., Pittsburg, Pa.
HERMAN L. VAN VALKINBURG,	With Westinghouse Elec. & Mfg. Co., Edgewood Park, Pa.

The following gentlemen were balloted for and duly elected to membership:

ALONZO L. CONNER, -	Mechanical Engineer, With American Tin Plate Co., McKeesport, Pa.
JOHN W. LANDIS, -	Manager, Pittsburg Office, The Goubert Mfg. Co., 501-2 Murtland Bldg., Pittsburg, Pa.
WILLIAM GARDNER SHROM, -	With Westinghouse, Church, Kerr & Co., 338 Atlantic Ave., Pittsburg, Pa.

The Nominating Committee announced nominations for officers for the ensuing year as follows:

President, H. W. Fisher; Vice President, Prof. F. C. Phillips; Secretary, C. W. Ridinger; Treasurer, A. E. Frost. Director one year, (to take place of Gustave Kauffman,) C. B. Connelly: Directors two years, J. M. Camp, Richard Hirsch.

It was voted that the report be accepted.

The following resolution was presented by Mr. Wilkins:

WHEREAS, A proposed bill regulating the spans and heights of bridges across the Ohio, Allegheny and Monongahela Rivers has been introduced in Congress.

AND WHEREAS, The said bill proposes to fix absolutely, irrespective of the local topography, width of channel and other conditions, the spans and heights of said bridges as follows:

On the Ohio River above Louisville and Portland Canal, 800 feet span, and below said canal, 1000 feet. Height above water to be not less than 40 feet, and not less than 90 feet above low water, if located above the mouth of the Big Sandy River.

On Monongahela River, channel span to be not less than 500 feet and head room above pool level not less than 54 feet.

On Allegheny River, span not less than 400 feet below Hickory Creek, and 250 feet if above Hickory Creek. Head room below Sixth Street Bridge, Pittsburg, 75 feet, and above Sixth Street Bridge and below Oil City, 60 feet.

AND WHEREAS, It is proposed to place the granting of the privilege of building bridges across these rivers in the hands of the Secretary of War, instead of by Congress, as under the present laws.

AND WHEREAS, Under the present laws governing the erection of bridges across these rivers, the length of spans is not absolutely fixed, but said spans are determined by a Board of Engineers appointed by the Secretary of War, said boards

considering each bridge with reference to the local conditions and fixing the spans and clearance with reference to these conditions; therefore be it

Resolved, That it is the opinion of the Engineers' Society of Western Pennsylvania that the present laws governing the erection of bridges across these rivers are eminently fair, both as to the river and bridge interests, and that it remonstrates against any change in the existing laws; and therefore be it further

Resolved, That these resolutions and preamble be sent to our Representatives in Congress, with the request that they present them to the Sub-Committee of the River and Harbor Committee.

Mr. E. K. Morse—I might say, in addition to what has been read, that there was a bill introduced in 1897 similar to what has been read here, and at that time the matter was taken up and a paper read by a member of this Society, who took the pains to go down the Ohio River as far as Rochester when the river stood at 11 feet 6, (which is a very good stage,) to the different islands where there had been numerous wrecks, and in no one place was it found that the pier of any bridge, as per bill introduced, stood in the river. An 800 foot clear span would go clear over the island where these places were dangerous. An 800 foot span at Beaver Railroad bridge would take out two spans of that bridge. Now, we don't want anything of that kind. We have islands, hundreds of them, between here and Wheeling. If an engineer were required to pick a part of the river for a railroad bridge to-day, he would naturally put one of the channel piers on an island, and the other thrown over clear out of the natural navigable channel. Should this bill be passed, to set this aside, you could not locate a pier on this island. A 600 foot span has been very seldom built. To-day we have no railroad bridge span 800 feet long. We are building more railroad bridges and longer spans than all the rest of the world put together, (I believe

many of the members will bear me out,) and for that reason I think it is one of the most important things that the Society can do, that should it be necessary, they send a delegation to Washington to meet the Committee of Harbors and Rivers. The passage of this bill would prevent any further railroad construction between here and Cairo necessitating a bridge across the Ohio River. Heretofore, it has only heen necessary to lay the matter before our Congressmen to prevent its going any further, and I think it will get no further now.

After discussion motion carried.

Mr. Schellenberg—A great deal has been said in the papers about the Polytechnic Institute Mr. Carnegie is to donate to this community. I don't know just what the intention is, and I don't know that we have any particular course to propose, but I think we might bring the matter up and find out what the general opinion is, in regard to what kind of a school is most needed.

The matter of Polytechnic or Trade School was then taken up and Mr. W. E. Snyder presented the following motion in regard to this matter:

Motion: That a committee of five be appointed to

(a) Define or explain in clear language the function of the Polytechnic School.

(b) Define and explain the function of the Industrial or Trade School.

(c) Point out their differences, especially as to requirements for admission, training given, and kind of work for which graduates are fitted.

(d) Draft suggestions as to which kind of school would be most appropriate for this community.

(e) Submit this in writing to the Society for discussion and action.

Mr. C. B. Albree—I have heard a great deal of discussion in regard to this very question as to what kind of a school it would be. As far as I can make out there is not the neces-

sity for a school for turning out finished engineers. We need an Industrial School more. Everybody seems to think that would be the very best thing. I have talked with some few members of the Carnegie Committee, and from what they said I think they would be very glad to receive any suggestions we might make, and I think Mr. Snyder's motion is a very good one. The committee could report to the Society and outline what they think would be a good thing. I think we are all interested in having something there that would be of interest to the city.

Mr. Wilkins—When I read over Mr. Carnegie's letter, making that offer, it did not seem altogether clear as to what he meant, whether it was to be merely an industrial or trade school, or a technical school like the Renassalær Polytechnic Institute, or the Massachusetts Institute of Technology.

Mr. Albree—Nothing has been decided, I think. It was merely talk on their part.

Mr. Snyder—What I had in mind is, that I do not think there is any body of men more capable of discussing what kind of a school is most needed here, than the Engineers' Society. If we do not discuss it and bring it before the public in some intelligent way, money may be donated here and spent in a way that will not be for the best interest of the community.

Mr. Schellenberg—I would indorse the motion made by Mr. Snyder. The newspapers are very anxious to have something to tell, and we ought to be anxious to tell them something to lay before the public. I think we ought to feel a responsibility in this matter. It is a very important thing. This may be a school different from any other, probably will be; it may have a range and scope that has not been attained by any other. I think the motion should prevail.

Prof. Connelley—Mr. Andrews, Supt. of Public Instruction in Pittsburg, has, since his inauguration into office, been trying to have industrial training introduced in the Public

Schools, and recommended in his report last year that measures should be taken to have a building erected where the children of the High Schools could receive manual training. Mr. Carnegie heard of this.

I think from what I have gleaned from some of the Commissioners of the Carnegie Institute, that it is not Mr. Carnegie's desire to have a Polytechnic School, but a school where young men can be trained as mechanics. Of course I cannot speak authoritatively on this. That is just what I have gleaned. I think Mr. Snyder's idea is a very good one.

After discussion motion carried.

The President then appointed Messrs. F. Z. Schellenberger, W. E. Snyder, C. F. Scott, C. B. Albree and C. B. Connelley to act as this committee.

It was voted that a committee of two be appointed by the Chair to audit the Treasurer's report, and the President appointed W. G. Wilkins and Charles Davis as Auditing Committee.

Next in order was reading of the paper of the evening entitled, "Methods of Locating Faults in Underground Electric Cables," by Mr. H. W. Fisher.

"METHODS OF LOCATING FAULTS IN UNDERGROUND ELECTRIC CABLES."

BY H. W. FISHER.

In preparing this paper it has been the object of the writer to mention quite fully many of the common methods which are used in daily practice. But in addition to these there will be found a number of original methods which have proved of great service to the writer at various times. This paper is intended to be a short, practical treatise which may possibly be of service to some of our engineers in case they ever need to do work of this kind.

Many of the treatises dealing with the location of faults in electrical cables are not very practical, and it often is difficult for and inexperienced engineer to obtain from them in the right shape the information which he desires. The methods in ordinary use for locating faults in cables are mostly simple and easily applied, errors frequently arise from carelessness on the part of the line-man who has in hand the connecting of wires at points removed from the testing-instrument.

Some of the causes leading to inaccurate results are wrong connections, poorly made joints or connections, uncalled for connections with other wires, inaccuracies in operating, or reading the instruments.

The complete apparatus which may be required for locating faults of various kinds consists of a reflecting galvanometer and its shunt, a telescope and scale or lamp and scale for said galvanometer, a Wheatstone bridge, a battery, a condenser, a 1-10 megohm resistance box, a discharge key, and sundry smaller and less important apparatus which will be mentioned when necessary later.

The kinds of faults under consideration will be grounded wires, crossed wires, and open or broken wires. Grounded

wires, or "grounds," as they are frequently called, are wires which are directly or indirectly connected with earth to such an extent that a certain amount of current may escape through the earth connection. Crossed wires, which are frequently called "crosses" or "contacts," are two or more wires between which an electrical contact is established by direct metallic connection, or by moisture, or by the carbonization of the exterior insulation due to electric burn-outs or fires. Open or broken wires are such in which a metallic continuity no longer exists on account of the wire being broken. Many forms of apparatus have been designed with a view to simplifying the making of electrical tests and locating faults. Some of such instruments will be on exhibition at the close of the reading of this paper. One of them, designed by the writer, has proved to be very satisfactory, and a fault can be located with it in a few minutes. It generally is possible to locate grounds or crosses with small portable testing-sets in which are contained a Wheatstone bridge, galvanometer, and battery.

But as such a set is not always sufficient to locate faults of high resistance accurately, mention will frequently be made of the Thompson and D'Arsonval reflecting galvanometers which are the most sensitive instruments for indicating or measuring very small currents of electricity. A rough way to express the sensibility of these instruments is to say that they are often sufficiently sensitive to detect the 1-1,000,000,000 part of the current of an ordinary cell of battery.

When such instruments have to be used they should be set up in a room or basement where the vibration of the building is as small as possible. Excessive vibration is a source of annoyance and may lead to inaccuracies. Thompson reflecting galvanometers can seldom be used in practical work because the magnetic needle is affected by electro magnetic disturbances due to the electric trolley railroads which are to be found in almost all towns or cities where cables are employed. D'Arsonval reflecting galvanometers are not so affected, and

when equipped with a telescope and scale they can readily be set up and used out-of-doors, which is often of great advantage.

When making measurements to locate faults, communication with a line-man or operator, located at the far end of the cable, is frequently established by means of a telephone or telegraph instrument. Directions for changes in the connections can thus readily be given, and much loss of time obviated. Line-men working for telephone companies are usually provided with a portable testing and talking set, which consists of a magneto bell capable of ringing through a resistance of 5000 to 10,000 ohms, and a telephone transmitter and receiver.

Before proceeding to make the necessary measurements to locate the fault it is always best to determine the nature and extent of the trouble. If the fault consists of grounds or crosses it is advisable to determine what the resistance of the fault or faults is, and then make tests to find one or more good wires to use subsequently when applying the test. This can be done by means of a battery used in conjunction with a voltmetre galvanometer, or Wheatstone bridge and roughly by means of a magneto bell or telephone and battery.

TESTING CABLES WITH A MAGNETO BELL.

The best magneto bells will ring very lightly through a resistance of about 50,000 ohms and the ordinary ones through 10,000 to 15,000 ohms. This important fact must not be overlooked, that a magneto bell will ring through a cable whose insulation resistance is perfect, when the electrostatic capacity of said cable is sufficiently high.

Hence it is often difficult to tell whether the magneto rings on account of a leak in the cable, or because the electrostatic capacity is sufficiently large, or from both causes. Its indications, therefore, may not always be reliable, and when a doubt exists a voltmetre or galvanometer should be used. The ordinary and best magneto bells will commence to ring respectively through about .3 M.F. and .1 M.F., and will ring stronger

and stronger the more the capacity is increased. Both these last figures are based on a rapid rotation of the magneto handle. As almost all magneto bells can be made more or less sensitive by a slight adjustment, both figures are only approximate and represent average results.

TESTING CABLES WITH A TELEPHONE RECEIVER AND BATTERY.

An extremely simple and cheap way to determine whether or not the insulation resistance of any particular wire is high or not is as follows:

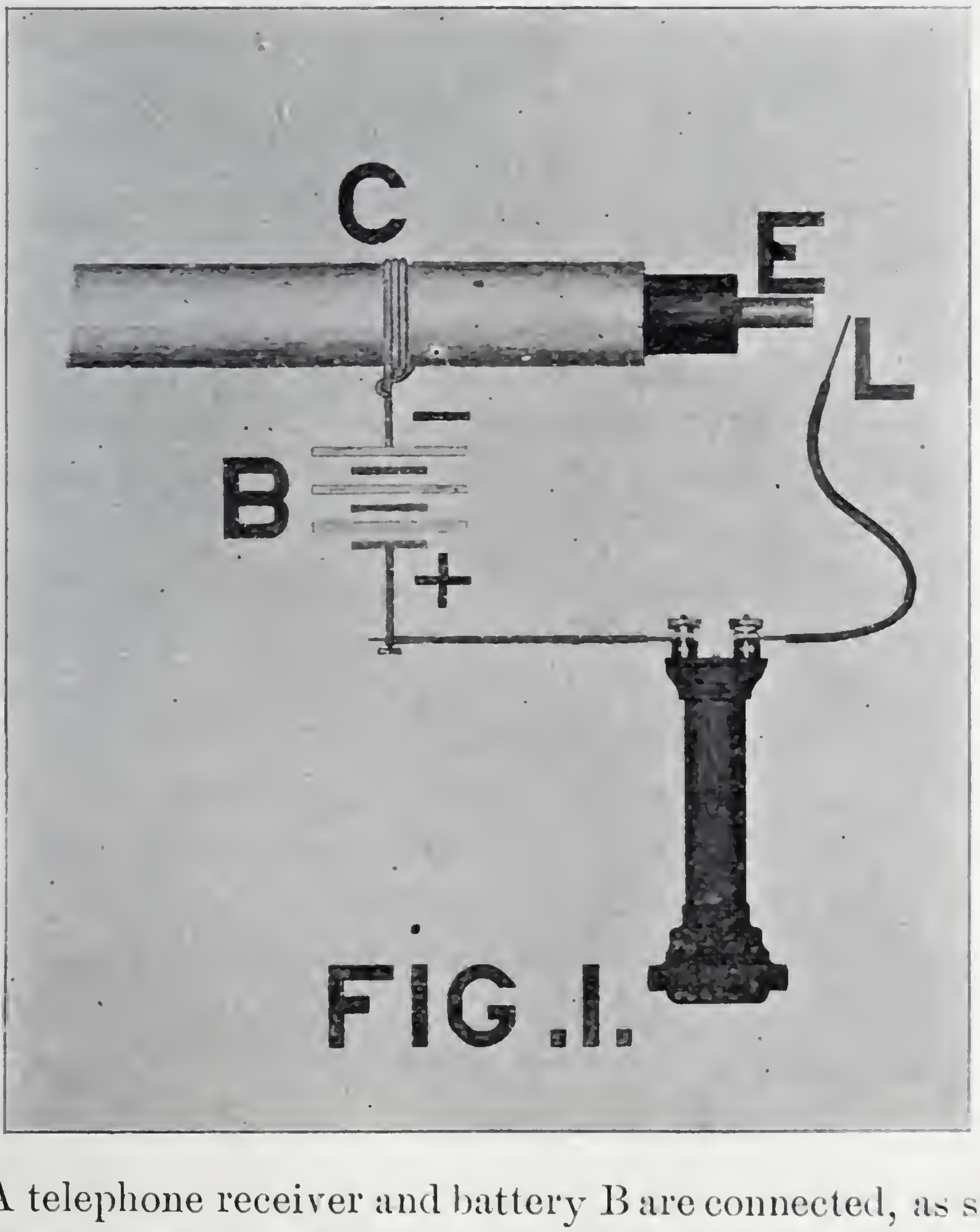


FIG. I.

A telephone receiver and battery B are connected, as shown in Figure 1, where one side of the battery is connected to the

lead of the cable C or to ground, and the other side to a telephone receiver. A rubber insulated wire should be attached to the other side of the telephone. To apply the test, press the telephone receiver to the ear, and touch the wire L to the conductor E; a click will always be heard the first time. After keeping both wires in contact for several seconds, break and make the connection once more; if no sound is heard at the instant of reconnection the wire is not faulty. This is explained as follows: The first click was due, at least in part, to a charging current from the Battery to the wire of the cable. Now, if the insulation resistance of the wire in question be good, this electrical charge is not soon dissipated, and hence during the space of the small interval of time between the break and make, the cable has not had time to discharge enough current to give a perceptible sound in the telephone at the instant of reconnection. If, on the contrary, the conductor is faulty there will be a decided click each time the connection is made.

Persons who have in hand the laying and testing of cables become familiar with this method; and can often estimate fairly correctly by the amount of sound the approximate insulation resistance of wires that are slightly faulty. The loudness of the click depends upon the particular telephone employed, the number and voltage of cells used, the electrostatic capacity of the cable, the resistance of the leak, the interval of time between the break and make of the circuit; hence it is difficult to give any data by means of which the approximate resistance of the leak can be obtained. Under ordinary conditions, however, in telephone cables reaching from about 1000 feet to a few miles in length, with intervals of the time between break and make of one second and with a battery of one volt it can be assumed that no click means at least a resistance of 50 megohms. When more battery is used this number is increased about in proportion to the number of cells. For a given voltage and a given insulation resistance there seems to be a

certain electrostatic capacity which gives the loudest click in the telephone. The writer found that with $1\frac{1}{2}$ volts, and a leak of about 150 megohms that there was an audible sound in the telephone when the electrostatic capacity was .1 or .2 of a micro-farad, and when the interval between make and break was about one second. While when the capacity was changed to .01 of a micro-farad or to .7 of a micro-farad no sound was perceptible when the interval between make and break was 1 second, but when the time was extended to 2 or 3 seconds a sound could be heard.

Experiments were made with a cable having an insulation of 5,000 megohms and with a battery which showed about 150 volts. A condenser was connected in multiple with the cable, and the capacity being varied it was found that no sound was perceptible when the capacity was as great as .7 of a micro-farad, that a sound could be heard when the capacity was .01 of a micro-farad and a very little louder sound when the capacity was .1 of a micro-farad.

It will be seen, therefore, that if sufficient battery is available that a cable which gives no sound in the telephone when subjected to this test must have a high insulation resistance.

The same method can be used to indicate leaks in circuits which do not have any electrostatic capacity provided that a condenser be put in multiple with the circuit and the ground, and that the insulation resistance of said condenser be perfect. This method cannot always be used successfully with cables which are transmitting telephone or telegraph messages, because when the wire is connected to the ground through a telephone there is apt to be a sound due to inductive currents from the other wires which cannot always be disassociated from the sound that might or might not be produced under more favorable conditions. When 5 or 10 cells are accessible the method can invariably be used on wires in a working cable to tell if said wires can be operated successfully.

TESTING RESISTANCE OF FAULTS BY WESTON VOLTMETER.

The Weston voltmeter is a convenient and satisfactory instrument for determining the resistance of faults through a range of from 1,000 ohms to a few million ohms or megohms. About 50 cells of battery should be used to give fairly accurate results. Voltmeters having a resistance of 10,000 ohms and

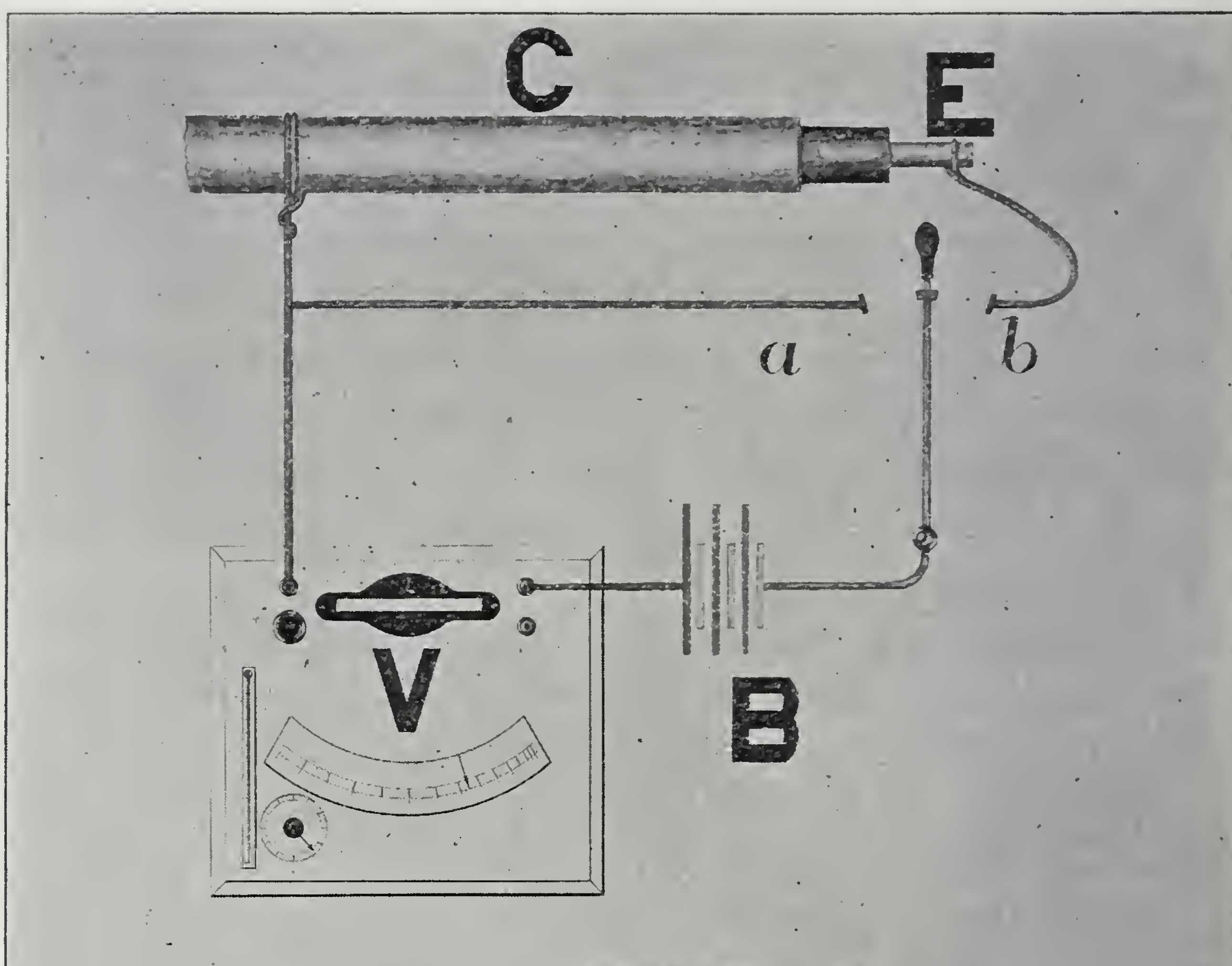


FIG. 2.

upward should generally be employed. The resistance of the fault is calculated from the formula :

$$\text{Resistance of the fault} = \frac{a-b}{b} \times R \qquad (1)$$

Where a = the volts read with the battery connected to the voltmeter.

Where b = the volts read with one side of the battery t

one terminal of the voltmeter, and the other side of the battery to the faulty wire, the remaining terminal of the voltmeter being connected to earth.

Where R = the resistance of the voltmeter, which is generally written upon a card pasted to the inside of the cover.

Figure 2 shows the respective connections.

B is the battery, V the voltmeter, C the cable, E the conductor. The letters (a) and b are placed respectively at the

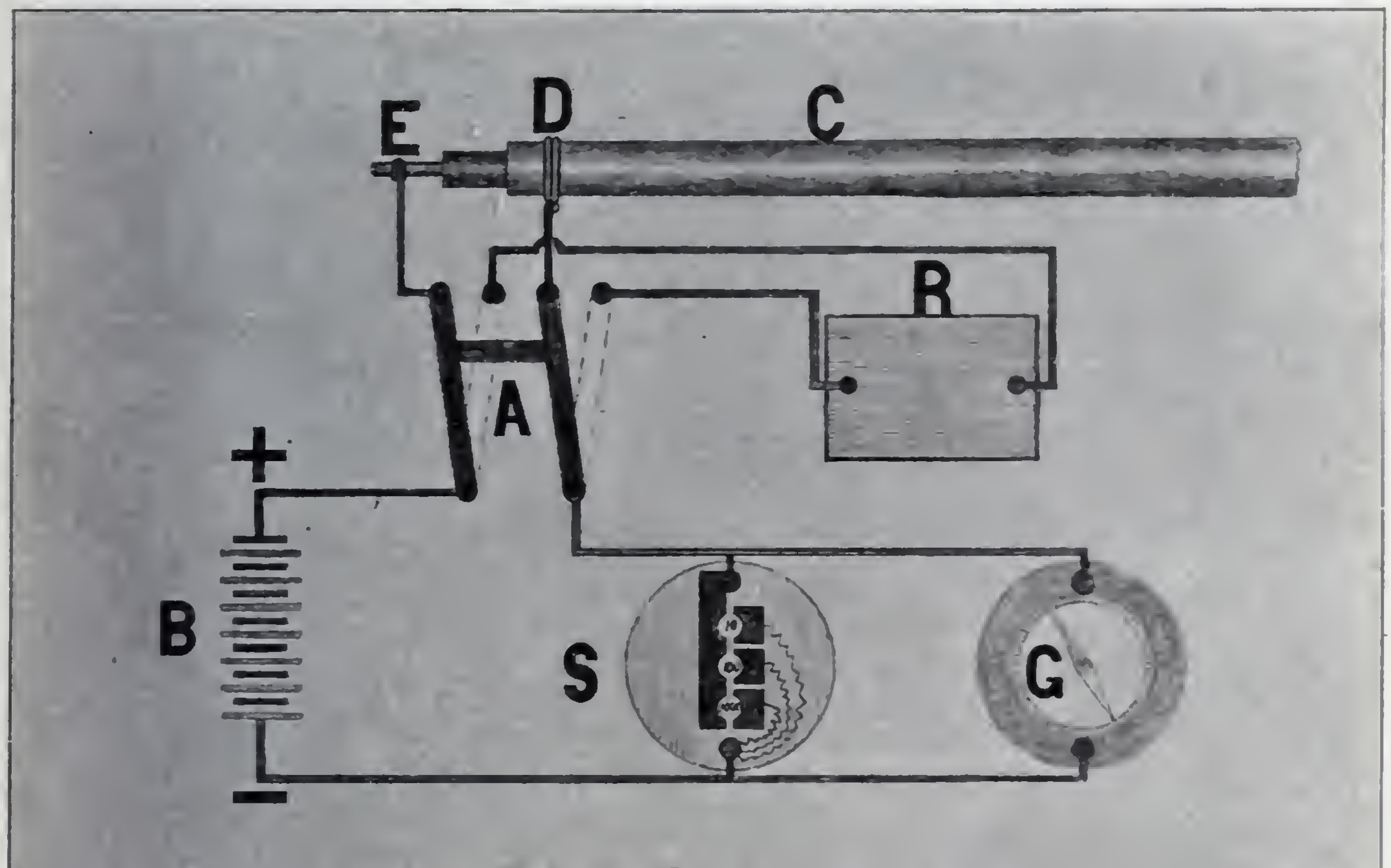


FIG. 3.

points that must be connected by the switch to give the readings designated by the same letters a and b above.

TESTING RESISTANCE OF FAULTS BY GALVANOMETERS.

Some of the D'Arsonval horizontal galvanometers which can be purchased in this country will indicate over 100

megohms with 50 cells of battery. They can be used to measure the resistance of faults in two ways, viz :

First, in connection with the Wheatstone Bridge, and second by the direct deflection method, as shown in Figure 3.

First, by Wheatstone Bridge.

The Wheatstone Bridge, illustrated in Figure 4, is so well known by engineers, and so thoroughly well described in test books that it is not in the province of this paper to enter into a detailed description of it. As generally constructed, resistances of a fraction of an ohm up to about 1,000,000 ohms can be measured in this way.

In Figure 4 A and B the ratio arms of the bridge can generally be made 10, 100, or 1,000 ohms.

D the adjustable or variable resistance has a range from 1 to 10,000 ohms.

C is the unknown resistance, and E the battery.

The resistance D is varied till the galvanometer G shows no deflection, when a balance is reached and $C = \frac{A}{B} \times D$ (2)

Second, by Direct Deflection.

In the direct deflection method a comparison is made by means of a galvanometer between a standard of resistance and the unknown resistance. The method is illustrated by Figure (3), where B is the battery, G the galvanometer, and S its shunt, R is the standard of resistance which is generally 100,000 ohms or 1-10 megohm, C is the cable and A a double-pole switch.

The shunt is an instrument provided with resistances which can be placed in multiple with the galvanometer by plugs, and which bear ths right relation to the resistance of the galvanometer, so that respectively 1-10, 1-100 or 1-1000 part. of the battery current can be made to pass through the galvanometer, the remainder going through the shunt.

The total current is found by multiplying the galvano-

meter current by 10, 100, or 1,000, depending on the particular shunt used, and these figures are called the multiplying power of the shunt. If such a shunt is not available, a resistance box can be used for a shunt, in which case the multiplying power of the shunt $= \frac{s + g}{s}$ (3) where s = the resistance of the shunt.
where g = the resistance of the galvanometer.

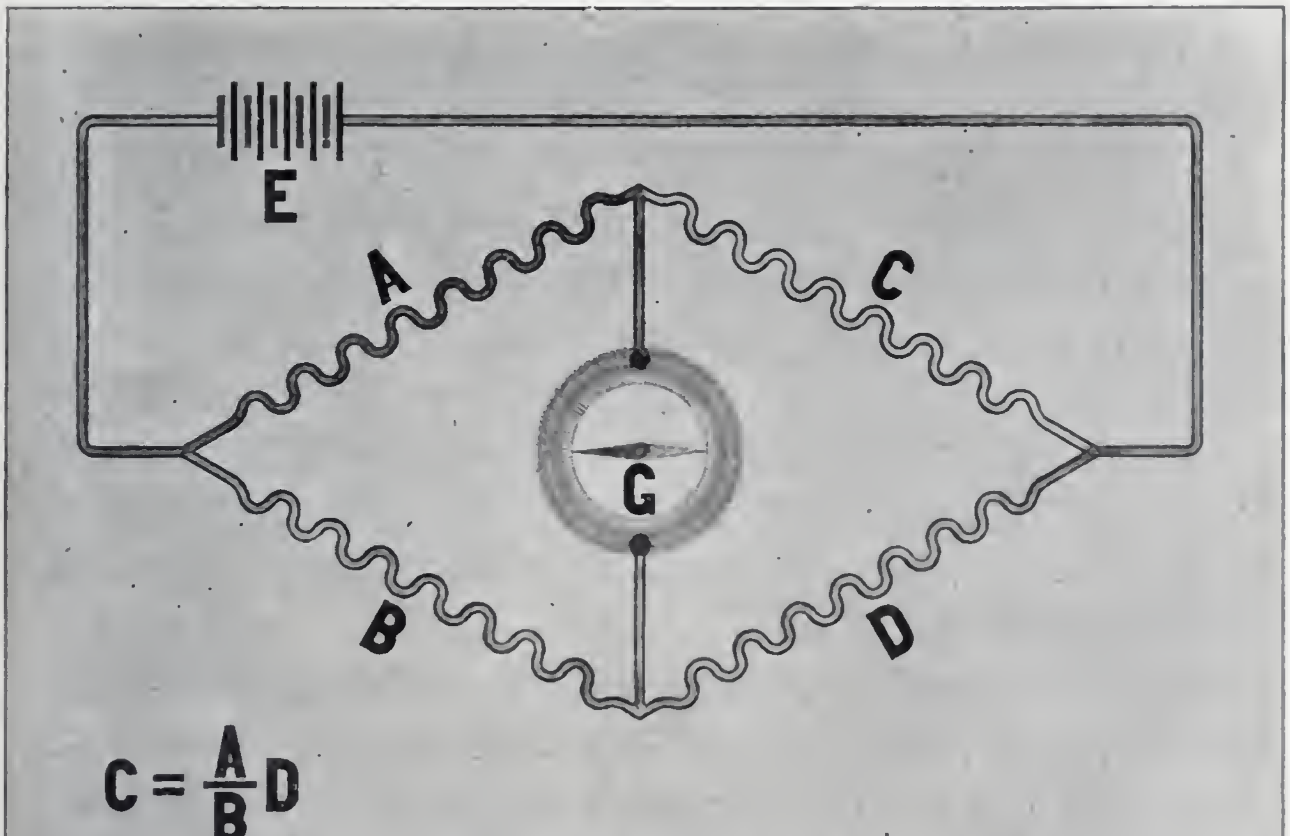


FIG. 4.

To apply this method the connections illustrated by the dotted portion of the switch are made, and a shunt is employed which will give a good readable deflection of the galvanometer.

Let d = said galvanometer deflection.

Let m = multiplying power of shunt.

Let R = the value of the standard resistance.

Then,

$d \times m \times R$ = The constant of galvanometer = G =

the number of ohms or megohms, as the case may be, which correspond to 1 scale division of the galvanometer.

The 1,000 shunt is now applied, and the switch placed in the position represented in the figure. If no deflection is obtained, lower shunts as used, and if necessary no shunt.

The galvanometer deflection is now read.

Let d^1 = said galvanometer deflection.

Let m^1 = the multiplying power of shunt which = 1 when no shunt is used.

Then the insulation resistance of the wire under test = $\frac{G}{d^1 \times m^1}$ (4).

This method is generally used to measure very high insulation resistances, and is perhaps more applicable to tests preliminary to locating broken wires than to the case of grounds and crosses.

When applying it to the latter it is well to place the standard resistance box in the circuit and substract its resistance from the total measured resistance to obtain the resistance of the fault.

The above methods have been considered more fully than might seem necessary at first sight because, in order to locate grounds and leaks accurately, one or two good wires are generally needed, and hence it is quite essential to be able to determine in an approximate manner the insulation resistance of the wires under consideration.

Faults on electric light, power, and telegraph cables are apt to be quite low in resistance on account of the high voltages used and the burn-outs caused thereby when faults become of sufficient magnitude to affect the working of the system. Faults on telephone cables are seldom less than a few hundred ohms, and frequently run from a few thousand to a megohm. Faults in telephone cables, measuring as high as 50,000 ohms, can be located fairly accurately with a good reflecting galvanometer and 50 cells of battery. In order to locate faults of

much higher resistance than this, an extra sensitive galvanometer and battery of 100 or 200 cells are needed. It is practically impossible to locate accurately a high resistance fault in an electric light cable of large size, with a Wheatstone Bridge, battery and galvanometer. However, in electric light stations, the means are generally at hand by which such a fault can be made quite low in resistance by the application of sufficient electric current.

Commercial copper wire of any particular size is apt to vary in resistance as much as 3%, which is largely due to variations in the diameter of the wire; hence there is always a chance for a difference between the actual and calculated distances to the fault, for the latter depends on the assumption that the resistance is equally distributed throughout the entire length of the cable.

Occasionally faults have to be located in two cables which are joined together, and one of which contains conductors of a different size from the others. A method for doing this will be found toward the end of the paper. Sometimes there are no good wires accessible in the faulty cable, and if no other cables having terminals adjacent to those of the faulty cable are accessible, it may become necessary when applying the test to use an overhead aerial conductor in conjunction with the faulty wire. Under these conditions if there are overhead trolley wires running parallel or nearly so to the overhead wire used in the test, inductive electric currents will be generated in said wire in such magnitude as to often make it impossible to use the galvanometer while the cars are running; hence as a lead cover shields the conductors from such inductive effects it is generally advisable to use all wires in lead covered cables, otherwise it may be necessary to make the tests after midnight, when the conditions are apt to be the most favorable. Another difficulty arising from the conjoint use of overhead and underground conductors is caused by the

change of resistance of the former due to the fluctuating temperature to which it may be subjected.

MURRAY LOOP TEST FOR LOCATING GROUNDED OR CROSSED WIRES.

This method is most convenient and applicable when one good wire of the same size and length as the faulty wire is accessible, and hence as given here it will only be applicable to such a case. This is the simplest method for locating grounds, crosses or leaks in cables. A variation in the resistance does not have an appreciable effect upon the result. This method cannot be expected to give as correct results as the Varley Loop method under favorable conditions, where, by making several measurements, all the available data to insure accurate results is obtained. Its great simplicity recommends it, especially for underground work, where it is generally only necessary to locate the fault between man-holes.

The method of procedure is about as follows :

Set up the instruments, and determine by any of the methods previously mentioned the approximate resistance to ground of some of the available wires. If the best wire has an insulation resistance of about 10 or more times higher than the worst wire, fairly good results can be obtained under ordinary conditions where the cables are not very long. Faults have been located fairly accurately when all the available wires were about equally bad, but such cases are no doubt due to coincidences depending largely upon the location of the faults. The method is most easily applied by connecting the cable directly to the instruments, but if this cannot be done two wires, called "leading wires," of the same size and length, will have to be used to connect the instrument to the cable. Connect very carefully and thoroughly one leading wire to the good wire and the other leading wire to the bad wire in the cable. The good and faulty wire must be connected at the far end of the cable. The other ends of the

leading wire are connected to the Wheatstone Bridge in the regular manner, and in order to work with some system, the one leading to the faulty wire should be connected to the variable resistance binding post or connector. Then plugs are inserted so as to cut out all of the ratio resistances adjacent to the variable resistance. The 1,000 ohm coil of the other set of ratio resistances should be used and designated A′. An inspection of Figures 5 and 6 will show that the galvanometer G is connected to the juncture of the leading wires and the

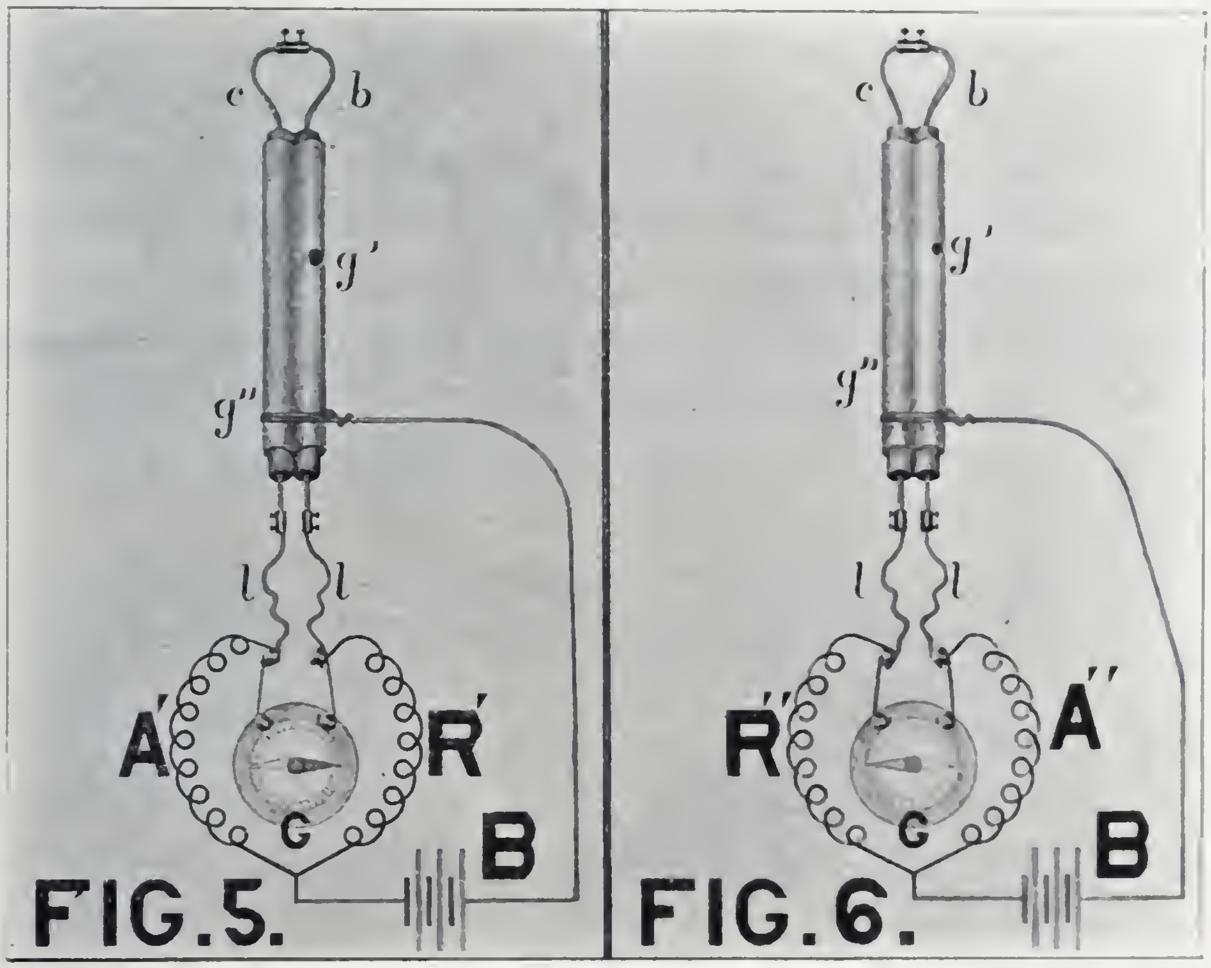


FIG. 5. FIG. 6.

Wheatstone Bridge, which is not in accordance with the usual connections made between the galvanometer and the regulation W. Bridge.

The Figures designated above will show that one side of the battery is connected at g″ to the lead cover of the cable, and the other side of its usual connector at the juncture of the two sets of ratio resistances. In the case of a cross the battery wire going to ground should be connected to the wire crossed

with the faulty wire used in the test. b represents the bad wire and c the good wire, l, l the leading wires and g′, g″ the ground connections, the former being the fault. The resistance is now adjusted in the variable resistance box until a balance is obtained in which case there will be no movement of the galvanometer needle. The value of the resistance required to give a balance is recorded and designated R′.

CHECK METHOD.

A check method can easily be applied by reversing the eading wires at the Wheatstone Bridge, and then by the removal or insertion of plugs in the variable resistance box obtain a new balance which we will call R″, see Figure 6.

If a balance cannot be obtained when making this last test, it will be necessary to reduce the ratio resistance from 1,000 ohms to 100 ohms, or possibly 10 ohms. The particular valued used should be recorded and designated A″. The letters A′, R′ and A″, R″ are shown respectively in Figures 5 and 6.

Letting L = the length of the cable, = $\frac{1}{2}$ the length of the entire loop, and assuming that the tests are made without the use of leading wires, the distance to the fault by the first test =

$$\frac{2 \times R'}{A' + R'} \times L \qquad (5)$$

and, by the check test the distance to the fault =

$$\frac{2\ A''}{A'' + R''} \times L \qquad (6)$$

If the test has been carried through correctly $A' \times A''$ should $= R' \times R''$. If leading wires which are equal in size to the wires of the cable are used, L must be increased by the length of one leading wire in the above formulæ, and then the length of one leading wire must be subtracted from the calculated distance to fault in order to give the corrected distance to the fault.

In order to make this method applicable when leading wires different in size from the cable wires are used, it will be necessary to introduce into the two above equations a new term, which will call l, and which equals the length of a wire of the same diameter as that of the cable wire, which would have a resistance equal to that of one leading wire. l can be found in two ways.

First, measure the resistance of one leading wire and divide it by the rated resistance per foot of a wire equal in diameter to that of the cable wires. This can be obtained from the table on page 365 containing the resistance of wires of different sizes.

Second, multiply the length of one leading wire by its rated resistance per foot and divide the product by the rated resistance per foot of the size of the wire in the cable. Introducing the values of l thus found in the new formula, the distance of fault by the first method =

$$\frac{2 \times R' \times (L + l)}{A' + R'} - l \qquad (7)$$

and, by the check method distance to fault =

$$\frac{2 \times A'' \times (L + l)}{A'' + R''} - l \qquad (8)$$

In practice the leading wires are generally short and are selected of a size about equal to the wires in the cable. l in equations (7) and (8) is therefore made equal to one leading wire. If the leading wires are short and differ by one or two sizes from the cable wires the error thus introduced may not amount to more than a few feet, which, in most cases, is negligible.

VARLEY LOOP METHOD OF LOCATING GROUNDED OR CROSSED WIRES.

We will now take up the question of locating faults by means of the Varley Loop. In the application of the Varley Loop several measurements are made by means of which we

are enabled to calculate the exact resistance of that part of the faulty wire between the end of the cable and the point where the fault is located. If in addition to this we can obtain correctly the total resistance of the faulty wire we can divide the resistance to the fault by said total resistance, thereby obtaining a ratio which when multiplied by the length of the cable gives the distance to the fault.

We will first consider the question of obtaining the actual resistance of the faulty wire between the end of the cable and the fault, and afterwards several methods of obtaining the actual resistance of the faulty wire under conditions which may occur in practice. Figure 7 illustrates the connections for the regular Varley Loop test, and Figure 8 illustrates the connections for a check method.

b is the bad wire, c the good wire, s′ and s″ the leading wires, B the Battery, G the galvanometer, R′ and R″ the adjustable resistances A′ B′, A″ B″ the ratio arms of the Bridge, g′ the fault. A careful examination of both these Figures will show that only one connection is made different from the ordinary plan of the Wheatstone Bridge, viz.: that the side of the battery, which is usually connected to the juncture of the adjustable resistance and the line, is in this case connected to ground represented by g″. The method of procedure is first to determine the resistance between the wire and ground of a few wires in the cable by one of the methods heretofore described. If all the wires in the cable are badly grounded, it will be necessary to form a loop circuit through another cable or through an aerial wire, or sometimes by the combination of both.

Having thus obtained a good and bad wire, said wires are thoroughly connected at the far end of the cable, which is designated by the letter m. Leading wires s′ s″ serve as a means of connecting the good and bad wires with the Wheatstone Bridge.

After setting up the instruments and making the connec-

tions the first step is to determine by means of the Wheatstone Bridge the total resistance of the circuit which includes the resistance of the leading wires s′ s″, and that of the bad and good wires b, c. This resistance we will call r. The battery connection for this test is shown by the dotted line.

One side of the battery is now connected to ground g″ as shown in Fig. (7) or, in the case of a cross, to the wire crossed with the one which is used in the test, and the variable resistance is adjusted until there is no movement of the galvanometer needle when the requisite balance is obtained. Said resistance is designated R′ in the diagram, and the actual resistance must be recorded without any consideration of what the resistance of the ratio arms of the Bridge may be. A′, B′, represent the ratio arms of the Bridge and A′ will generally be 10 or 100 and B′ 1000.

CHECK METHOD.

After recording the particular values used the leading wires are reversed at the terminals of the Wheatstone Bridge, and a new value R″ which is required to give a balance is next obtained. This with the values of A″ and B″ should then be recorded.

The resistance of the leading wire s′, which is connected to the faulty wire, must next be determined.

If the leading wires are of the same size and length, take one-half their combined resistance as the value of s′, otherwise the actual resistance of s′ must be found from direct measurement when both ends are available, or by the employment of formulæ (20) and (21), when a third wire is accessible and both leading wires are fixed, or by the following special method of the writer, which has frequently been found of great advantage when both ends of each leading wire are not within reach of the Wheatstone Bridge and no third wire is available.

Completely reverse the leading wires in Figure 7 so that s′ takes the place of s″, and vice versa. Then find the resist-

ance R″′ to balance in the same manner that R′ was obtained, then, letting S equal the combined measured resistance of the leading wires, —

$$s' = \frac{S}{2} + \frac{A' \times (R''' - R')}{2\,(A' + B')} \qquad (9)$$

The ratios A′ and B′ must of course be the same in each test, and the terms R″′—R′ must be taken in the algebraic sense, viz., the difference between R″′ and R′ must be taken and the

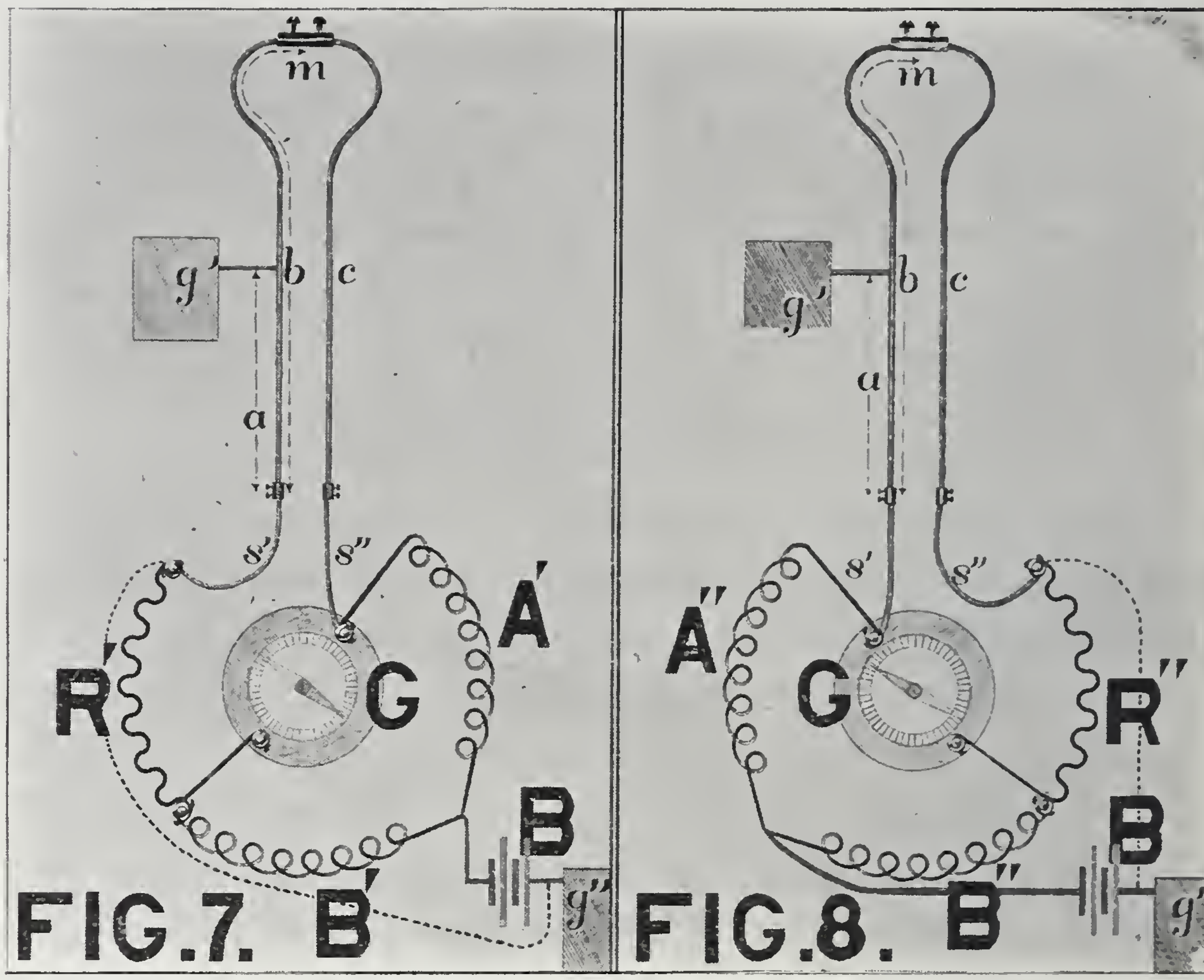


FIG. 7. FIG. 8.

value of the last term of the equation added or subtracted as R″′ is greater or less than R′. If R″′ equals R′ then one leading wire equals the other in resistance.

If there is any doubt as to whether the leading wires differ in resistance, this formula will at once settle the matter and can readily be applied. On one occasion the writer had to use two overhead wires which ran a distance of over 150 feet from where the instruments were located to the end of the cable. The necessary measurements being made, a calculation showed

the fault to be about 30 or 40 feet beyond the end of the cable, which of course was an impossibility. The leading wires were of exactly the same length, and the writer, suspecting that the discrepancy must be due to said wires, learned from inquiry that one of said wires was put up without a joint, while the other one had to be spliced at several points. Iron wires being used, the jointed one would have a higher resistance than the other one. The above method and formula were then devised and applied, and the writer's surmise was verified, after which the correct value of s′ being used, the fault was located accurately near the distant end of the cable.

The resistance of the faulty wire to the fault a and a′ can now be calculated from the following formulae:

$$a' = \frac{B' \times r - A' \times R'}{A' + B'} - s' \quad (10) \text{ by 1st method.}$$

$$a'' = \frac{A'' \times (r + R'')}{A'' + B''} - s' \quad (11) \text{ by check method.}$$

The average resistance to fault $= a = \dfrac{a' + a''}{2}$

Then the distance to the fault $= \dfrac{a}{b} \times L \qquad (12)$

In the above formula A′, A″, B′, B″ equal respectively the ratio resistance used in the Wheatstone Bridge, as indicated in Figures 7 and 8, R′ and R″ equal respectively the actual resistances found necessary to make a balance, s′ equals the resistance of the leading wire adjacent to the bad wire. r equals the combined resistance of the leading wires and the bad and good wires, as shown in the diagrams $s' + b + c + s''$.

L = the length of the cable.

b = the resistance of the bad wire (see next section).

METHODS OF OBTAINING (b) THE RESISTANCE OF THE FAULTY WIRE

1ST CONDITION.

When only one good and one bad wire are accessible.

Under these conditions b cannot be determined accur-

ately with any degree of certainty, although frequently it may be determined sufficiently close to give very good results.

When the good and bad wire are in the same cable, and are both the same size, the value of b is found by taking one-half the combined resistance of the good and bad wires, and as thus determined is generally sufficiently close to give good results.

Let S = the combined measured resistance of the leading wires running from the Wheatstone Bridge to the Cable.

Let r = the total measured resistance of the good and bad wires and the leading wires.

Then, for this case $b = \frac{r-s}{2}$ (13)

We will next consider the case of a good and bad wire of different known lengths and sizes.

If both wires are at practically the same temperature proceed thus :

Let L' = the length, and

Let R' = the rated resistance per 1000 feet of the bad wire.

Let L'' = the length, and

Let R'' = the rated resistance per 1000 feet of the good wire. Then

$$b = \frac{L' \times R' \times (r-s)}{L' \times R' + L'' \times R''} \quad (14)$$

The values of R' and R'' can be found in the table on page 365.

The last case to be considered under this particular heading will be that of a good wire of an unknown length or size, or both, and a bad wire of known length and size.

Under these conditions it is unnecessary to measure r as we can only get at the approximate value by calculating its resistance from the table mentioned above.

Using the same letters as above for the length and resistance per 1000 feet of the faulty wire,

$$b = \frac{L' \times R''}{1000} \quad (15)$$

This formula is approximately true if the faulty wire has an approximate temperature of about 68°F.

The value of b must be increased by 1% for each 5° in temperature that the wire is above 68°F, similarly b must be decreased 1% for every 5° that the cable is below 68°F.

If the length and size of the good wire are known, and those of the bad wire unknown, calculate the resistance of the good wire in a manner similar to that just given and subtract said resistance plus the resistance of the leading wires from the total measured resistance of the loop to obtain b.

2d CONDITION.

When one good wire and two bad wires of the same length and size are accessible.

Occasionally in practice all the wires of a cable become defective, owing to a hole in the lead cover, which is caused possibly by mechanical injury, electrolysis, or chemical action.

Aerial cables are frequently injured by bullets which have been shot into them on days of celebration, such as July 4th.

If a good wire is not available for a test, it often happens that one can be made so, either through some other cables, or by the use of an aerial wire, or by the combination of both. Under these conditions b can be determined very accurately in the following manner :

Measure the resistance of,

1st. The good wire in series with one bad wire.

2d. The good wire in series with the other bad wire.

3d. The good wire in series with the two bad wires in multiple.

Let b and b′ represent the respective resistances of the bad wires.

Let c represent the resistance of the good wires.

Let r, m and n represent the resistances measured as above indicated.

Figure 9 shows the three sets of connections, and under-

neath each is the letter corresponding to the total resistance of the circuit. The resistance of the leading wires s', s'' does not enter into the calculation, and hence need not be considered.

The correct formulæ giving the values of b and b′ in terms of r, m and n are a little difficult to solve, hence we will give two approximate formulæ which are accurate enough for all practical purposes where r and m do not differ by more than 2 or 3%.

$$b = \frac{3\times r+m}{2} - 2\times n \quad (16)$$

$$b' = \frac{3\times m+r}{2} - 2\times n \quad (17)$$

The theoretically correct equations for b and b′ in terms of r, m and n are as follows:

$$b = r - n + \sqrt[2]{n\times[n-(r+m)]+r\times m} \quad (18)$$

$$b' = m - n + \sqrt[2]{n\times[n-(r+m)]+r\times m} \quad (19)$$

The resistance of wires of the same size in a cable do not generally differ by more than 2 or 3%, hence the approximate formulæ can be used in most cases.

It frequently happens that while several good wires may be available, yet on account of the interruption to the service through the failure of the faulty wires, only one good wire can be spared. Under such conditions the above method can be applied readily and good results obtained.

It must be understood that this method cannot be safely applied to the case of two faulty wires which happen to be of the same size and length, and end at the same points, but which do not have their respective faults at equal distances from their ends. If the resistance between the faulty wires and the lead cover and ground is high, say 2000 ohms, or more, the results obtained can still be considered good enough for practical purposes. By applying formulæ (10) and (11) the resistance to the fault of each bad wire in turn can be determined, and if

said resistances are about equal, both bad wires can be considered to have their respective faults at the same point.

When the wires in a telephone cable begin to fail one after the other, the faults will almost invariably be found at the same point. When the resistances of the faults are low, and

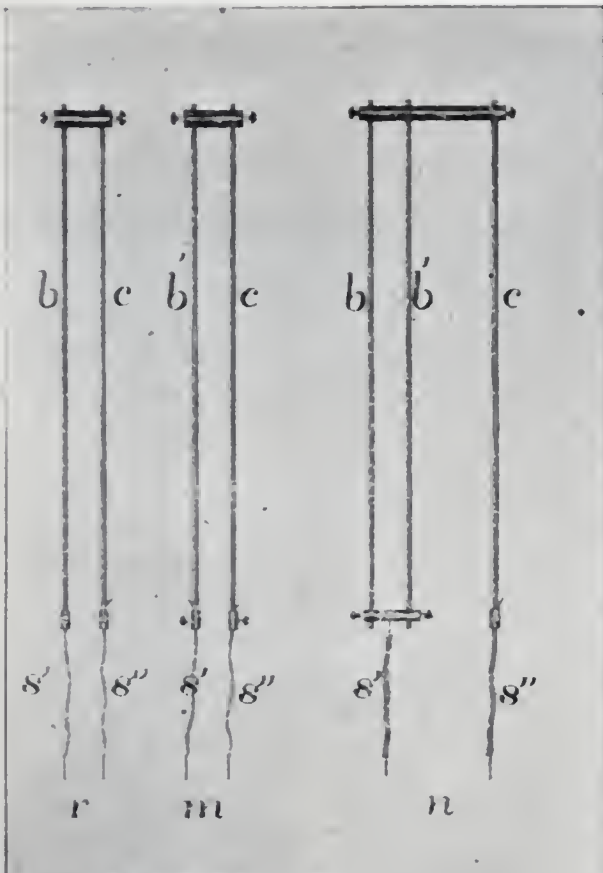


FIG. 9.

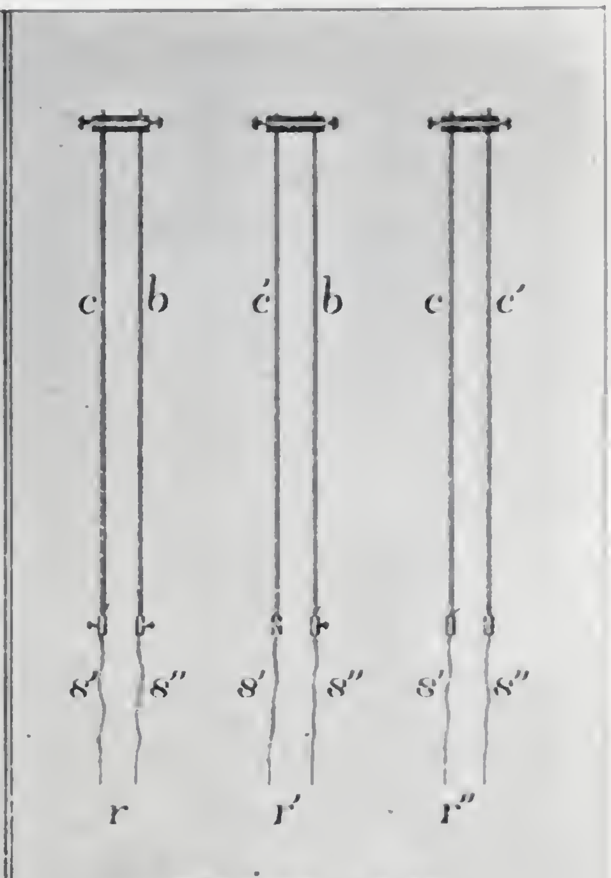


FIG. 10.

there is a possibility that each wire is grounded at different points, the next method should be applied.

3d CONDITION.

When two good wires, whose terminals are accessible to both ends of the faulty wires, are available.

Under these conditions the values of b can be determined accurately, which, of course means that the methods are the best for locating a fault accurately. It is not necessary that the good wires have the same resistance, nor that they follow the same route as the faulty cable. All three wires can differ widely in resistance and not in any way effect the test, neither

is it necessary that the leading wires running from the Wheatstone Bridge to the cable be of the same resistance, but the joint resistance of the leading wires must be measured.

Let c and c′ represent respectively the resistances of the good wires.

Let b represent the resistance of the faulty wire.

Let s′ and s″ represent the leading wires, and S their combined resistance. See Fig. 10.

Make in turn the three sets of connection represented in Figure 10, and measure for each case separately, the total resistance of the circuit, designated respectively by the letters r, r′ and r″ each of which is placed under the particular set of connections whose resistance it represents.

$$\text{Then } b = \frac{r + r' - (r'' + S)}{2} \quad (20)$$

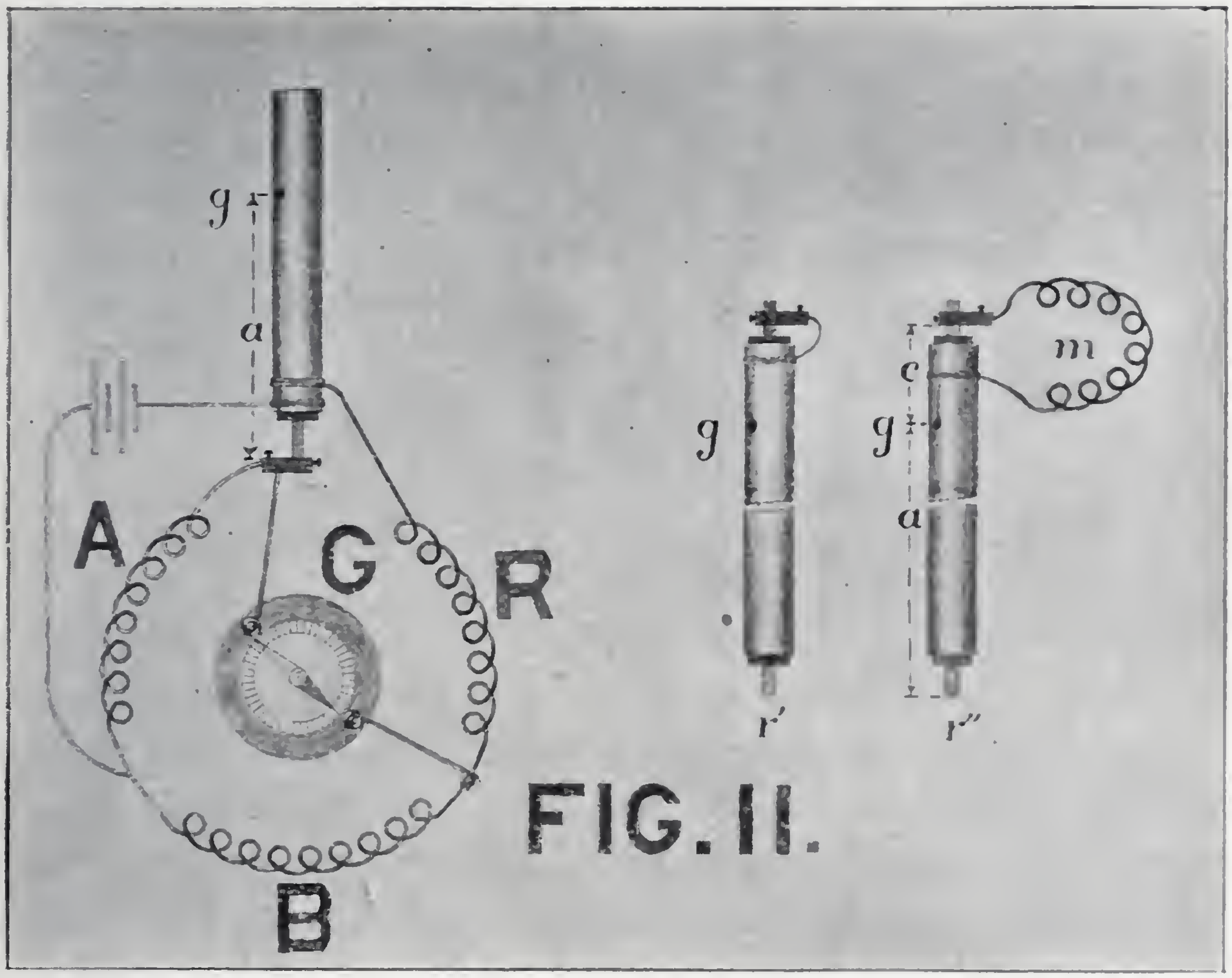
$$c = \frac{r + r'' - (r' + S)}{2} \quad (21)$$

The formulæ, representing the resistance of c, is given because this method has occasionally to be used to determine the resistance of two of three wires. Some times the instruments cannot conveniently be operated near the end of the faulty cable, and over-head wires, or wires through another cable have to be used for the leading wires. The above formulæ will serve to determine the individual resistance of two of such wires when a third wire is available. Before proceeding to make such test it is best to connect sufficient wire to each of the three wires to reach the Wheatstone Bridge, label the wires c, c′ and b, then follow the diagram and formulæ with this exception: Remove the term S from the formulæ.

METHOD OF LOCATING FAULTS WHEN NO GOOD WIRE IS AVAILABLE.

It is with reluctance that the writer enters into a brief description of methods of locating faults under the above condition, because said methods can seldom be applied except on

submarine cables, but this Paper would not be complete without briefly considering one of the commonest methods employed for such faults. The description given will be of Blavier's method and it is applicable to faults of low, unvariable resistances. Faults of variable resistance can be located by Ayrton & Perry's duplex partial earth test, but this requires apparatus which is not often accessible, and Galvanometers have to be used simultaneously at both ends of the cable, so that the



method, while applicable to submarine cables, cannot be readily applied to underground electric cables. A description of this method can be found in most Hand-Books dealing with tests of submarine cables.

To apply Blavier's method to the case of lead covered cables, the connections shown in Figure 11 are made. A and B are the ratio arms of the Wheatstone Bridge, R is the adjustable resistance, G the Galvanometer, B the Battery, the location of the fault is represented by g.

After making the connections shown, the resistance of the circuit which we will call r, is measured in the ordinary manner with the Wheatstone Bridge. If said resistance is variable it will be useless to try to locate the fault by this method. If, on the contrary, the resistance r is constant, the next step will be to connect the conductor at the far end of the cable to the lead cover of the cable, the connections to the Wheatstone Bridge being unchanged at the near end of the cable, after which the resistance of the circuit, which we will call r′, is measured.

The drawing above, r′, shows the connections at the distant end of the cable, and it is thought unnecesary to show the connections at the near end of the cable, seeing that they are already represented in the drawing above, r.′

Let a = the resistance of the faulty wire as far as the fault.

Let b = the total resistance of the faulty wire.

Let L = the length of the cable.

$$\text{Then } a = r' - \sqrt{(r-r')\ (b-r')} \quad (22)$$

and the distance to the fault $= \frac{a}{b} \times L$ (23)

If b, the total resistance of the faulty wire is not known, it may be approximately calculated by formula (15), but as this may not always be satisfactory, the writer has devised a modification of Blavier's method by which it is possible to calcalate a, the resistance to the fault, and also b, the total resistance of the faulty wire.

In order to do this the two measurements of Blavier's method just described are first made, and then a known resistance, which we will call m, is inserted between the conductor and lead at the distant end of the cable, the connections at the near end of the cable being unchanged. The drawing above, r″, represents the connections at the far end of the cable.

Let r″ = the total resistance of the circuit.

Let c = the resistance between the fault and the distant end of the cable.

We have $a = r - \sqrt[2]{\frac{m}{r''-r'}\left[r \times r'' - r\,(r' + r'' - r)\right]}$ (24)

$$c = \frac{a^2 - (r + r') \times a + r \times r'}{r - r'} \quad (25)$$

Now a + c = b.

Hence the distance of the fault $= \frac{a}{a+c} \times L = \frac{a}{b} \times L$ (26)

Where L = the length of the cable.

The resistance of the fault is equal to the term which has to be subtracted from r in equation. (24)

This method can only occasionally be applied in practice because faults generally have a variable resistance.

PRACTICAL METHODS OF LOCATING FAULTS WHEN THE ORDINARY APPARATUS IS NOT ACCESSIBLE.

The Wire Bridge Method.

The writer has applied this method very successfully both in locating faults in electric light cables having a cross-section as high as 1,000,000 C.M., as well as in telephone cables.

To apply this method it is necessary to have a good wire of the same size and length as the faulty wire. Figure 12 shows the connections. The good and bad conductors are connected at m, the distant end of the cable, g represents the location of the fault in the bad cable, a loop of wire is thoroughly connected to both conductors at the near end of the cable, and is represented by a circular line. G is the Galvanometer or volt meter, and in case neither are available a telephone receiver can be used.

In Figure 12 the current obtained from the Dynamo D passess through incandescent lamps L to the wire loop at b, whence it divides and returns to the Dynamo to the fault at g, in case such current is not available a battery can be used, but in such case the wire employed for the loop must have consid-

erable resistance. The direct current should be employed. When alternating currents are used a telephone, and not a galvanometer, must be employed, but then the right point of balance may not exactly be found on account of effects due to capacity and self-induction.

When locating faults on large electric light cable, a No. 4 or No. 6 bare copper wire should be used, and the fault ought to be located quite accurately with about 10 amperes of current.

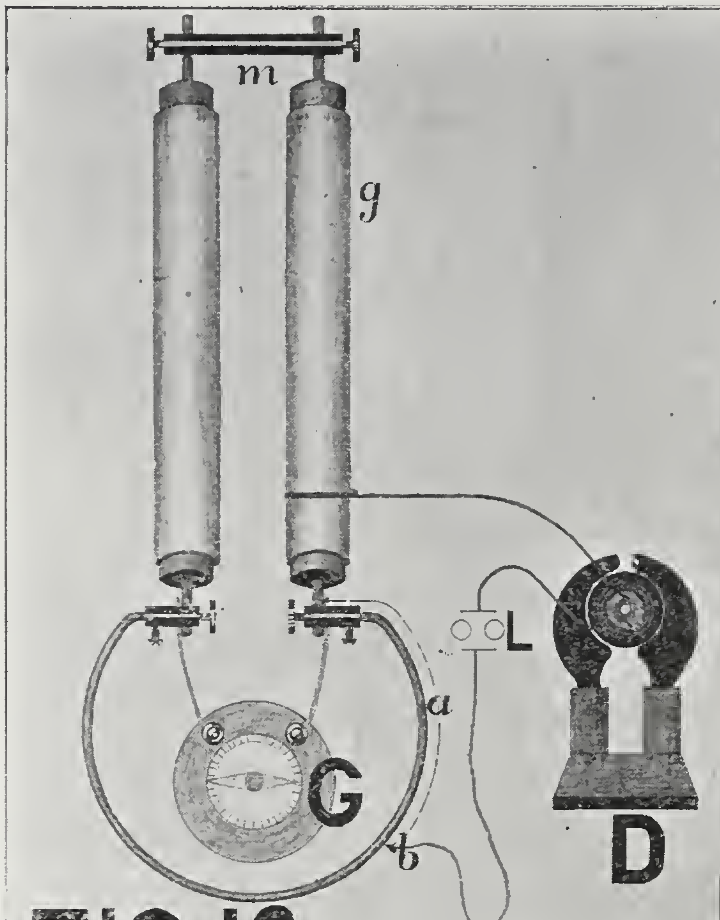


FIG. 12.

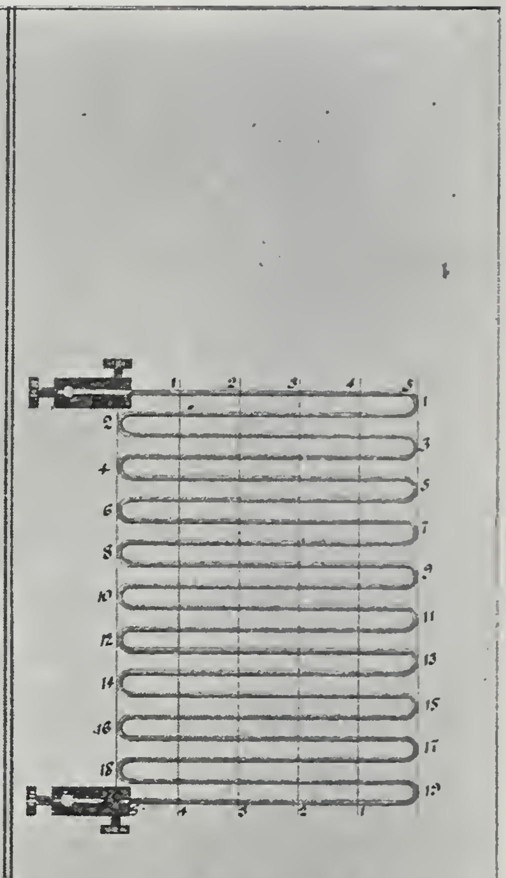


FIG. 13.

Having made the connections shown, it is only necessary to move the connecting point b along the loop until a balance is obtained, in which case the galvanometer needle will not be deflected. When a telephone is used, the point of balance will be located when there is no sound in the telephone, at the moment of making or breaking the battery circuit. Having obtained the point of balance b, the length of the wire from b to the faulty conductor is measured and is designated a.

Let l = the total length of the wire used in the bridge.

Let L = the length of the faulty wire or cable.

The distance to the fault $= \frac{a}{l} \times 2L$ (27)

For locating faults in electric light cables 15 or 20 feet of wire will be sufficient to give good results. For locating faults in telephone or telegraph cables, the writer has used a bridge of wire bent back and forth on a board in parallel lines, as shown in Figure 13. Lines at right angles to the above, and equally spaced, served as a means of reading the number of divisions from one end of the wire bridge to the point of balance.

WHEN THE FAULTY WIRE CONSISTS OF TWO WIRES OF DIFFERENT SIZES.

When a fault has to be located under the conditions specified in the heading, first determine the value of a, the resistance of the fault, and b, the resistance of the faulty wire, by the most suitable of the methods given.

Letting

L' = the length of the size of conductor adjacent to the testing instrument.

r' = the probable resistance of the above.

L'' = the length of the other size of conductor.

r'' = the probable resistance of the above.

R' = the rated resistance per 1000 feet of the first mentioned size.

R'' = the rated resistance per 1000 feet of the second mentioned size.

For values of R' and R'', see table on Page......

Then $r' = \dfrac{b \times L}{\frac{R''}{R'} \times L'' + L'}$ (28) and $r'' = \dfrac{b \times L''}{\frac{R'}{R''} \times L' + L''}$ (29)

If a, the resistance of the fault, is less than r', then the distance to the fault is $\frac{a}{r'} \times L'$ (30)

But if a is more than r′, then the distance to the fault is

$$L' + \frac{a - r'}{r''} \times L'' \quad (31)$$

METHODS OF LOCATING BROKEN OR OPEN WIRES.

Breaks in underground electric cables cannot be located as accurately as grounded or crossed wires can under favorable conditions.

The reason for this is because the tests are made by a comparison between the electrostatic capacity of the broken wire to the break, and that of a good wire running the full length of the cable. Now the electrostatic capacity of different wires in a cable is much more un-uniform than the resistance of the wire, hence the reason for the discrepancy. The electrostatic capacity of different wires in a telephone cable may vary as much as 5%.

If the insulation resistance of the broken wire is high, and the break is so complete that no current crosses at the point of rupture, the position of the faulty wire can be located accurately enough for most practical purposes. If, however, moisture has entered the cable in sufficient quantity to make the insulation resistance of the wires low, the fault cannot be located accurately with any degree of certainty.

This subject is a broad one, and very much would have to be written to treat it comprehensively, and hence the writer will confine himself to a few of the most practical methods.

The first thing to do is to measure the insulation resistance of the broken wire, and also of a good wire. If said insulation resistances are over 15 or 20 megohms the fault can be located all right. If the insulation resistance is as low as 1 megohm, the fault cannot be located accurately with any degree of certainty. This last statement is not necessarily true with reference to long submarine cables, where the conditions are different and where special methods are applied, and special instruments used, which are not generally practicable or accessible in dealing with underground electric cables.

There are two general methods by which breaks in cables can be located quite accurately.

FIRST METHOD.

In the application of this method the electrostatic capacity of the faulty wire as far as the break is measured, and also that of a good wire running the total length of the cable.

The former divided by the latter gives a ratio by which the total length of the cable is multiplied in order to get the distance to the fault. This method can only be applied successfully when a reflecting galvanometer is available, and hence, on account of the great length of this paper, it will be treated very briefly in order that more time may be given to the second and more practical method. Figure 16 illustrates the general connections which are used when measurements of electrostatic capacity have to be made. B is the Battery, G the galvanometer, K the discharge key, S a switch which serves to make connection to the conductor D of the cable C, or to the standard of electrostatic capacity L.

When the key is pressed down the point 3 is connected to 1 and the cable or condenser, as the case may be, is charged by the Battery. When the key is released the points 2 and 3 are connected, and the discharge goes through the galvanometer causing the needle to be deflected, said deflection being commonly called the "throw" or "discharge deflection" of the galvanometer.

FIRST CONDITION.

WHEN, IN THE CABLE CONTAINING A FAULTY WIRE, A GOOD WIRE IS AVAILABLE.

To apply this method to the above condition the Switch S, or its equivalent in the form of a wire, is connected to the broken wire and the discharge deflection, which we will call d, is observed.

Then similarly S is connected to a good wire, and the dis charge deflection, which we will call d′, is observed.

Let L = the length of the cable.

The distance to the fault $= \frac{d}{d'} \times L$ (32)

In the case of a telephone cable in which the wires consist of twisted pairs, it is best to use a mate of the faulty wire as the good wire referred to above, and if it is impracticable to

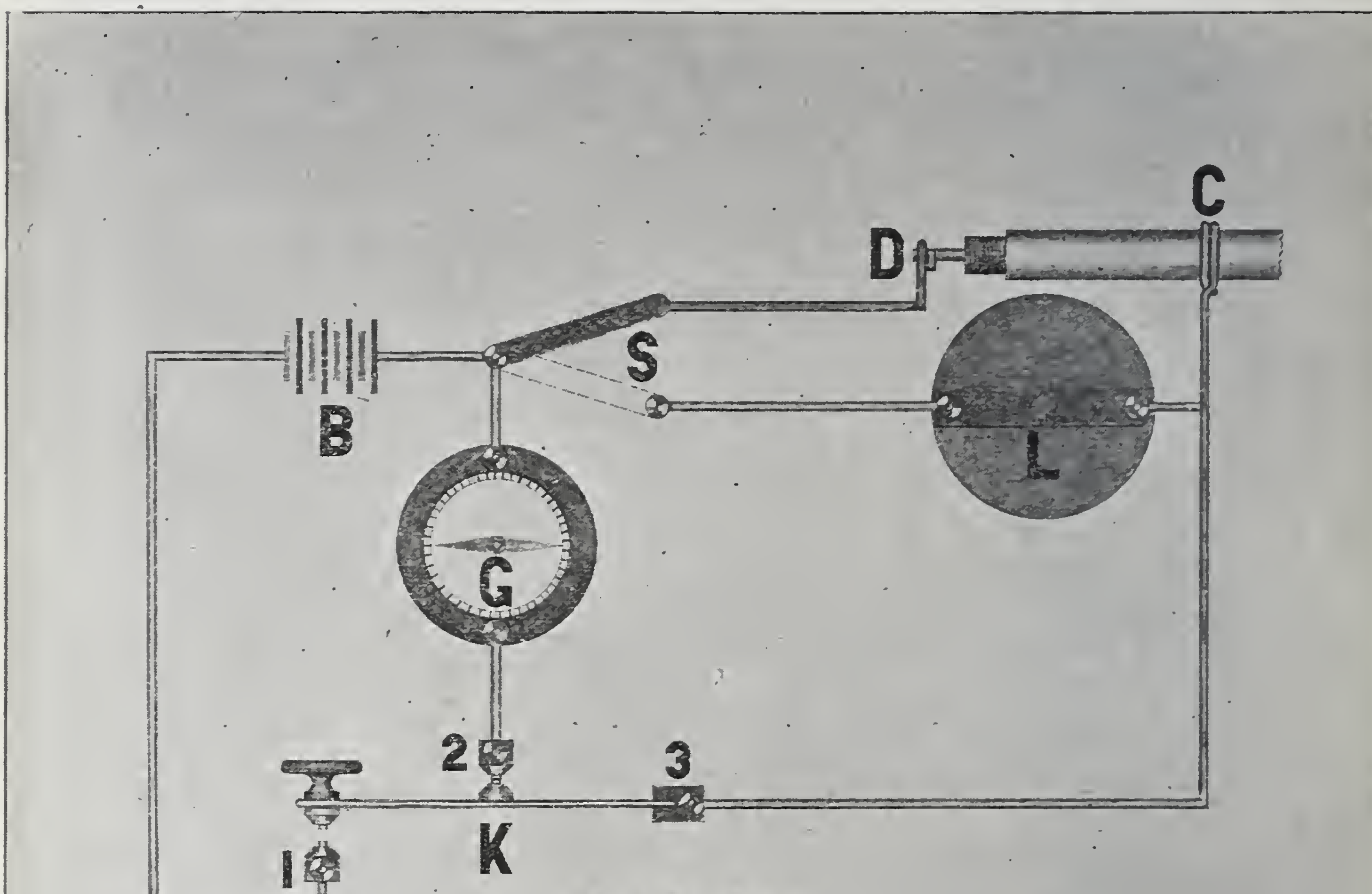


FIG. 16.

ground to the lead of the cable all the conductors in the cable, except the one used in making the test, the mate of the faulty wire should be grounded when the discharge deflection of the faulty wire is observed, and similarly both ends of the faulty wire should be grounded when the discharge deflection of its mate is being observed.

SECOND CONDITION.

WHEN NO GOOD WIRE IS AVAILABLE.

In this case it will be necessary to set up the instruments consecutively at each end of the cable as shown in Figure 16.

Let d = the discharge deflection of the broken wire from the first end of the cable.

Let D = the discharge deflection of the Condenser L when used at the first end of the cable.

Let d′ = the discharge deflection of the faulty conductor at the other end of the cable.

Let D′ = the discharge deflection of the Condenser L when used at the other end of the cable.

Let L = the length of the cable.

Then, the distance to the fault from the first end of the

$$\text{cable} = \frac{d \times L}{d + \frac{D}{D'} \times d'} \qquad (33)$$

The same amount of battery must be used throughout the tests at either end of the cable, but it is not necessary to use the same amount at one end that was used at the other.

SECOND METHOD.

The second method can, in almost all cases, be readily applied with very satisfactory results. It is a well known fact that an electrostatic capacity, when subjected to an alternating current or a reversed current, can be treated as a resistance, its equivalent being a resistance which, when subjected to the same voltage applied in the same manner, would allow the same current to pass. On account of this fact it is possible to compare capacities by means of resistances, and vice versa.

The equivalent resistance to a certain electrostatic capacity varies with the frequency of reversal or alteration, but this fact can be ignored in making comparisons if a balance method similar to the Wheatstone Bridge be employed, and if non-inductive resistances be used. In the subsequent treatment of

this subject it must be remembered that the resistances vary in reverse ratio to the electrostatic capacity, or, in other words, a large electrostatic capacity has a smaller equivalent resistance than a small electrostatic capacity.

The writer is indebted to Mr. Snyder, of the C. D. & P. Telephone Company, for the application of this principle to the case of telephone cables which is illustrated in Figure 14.

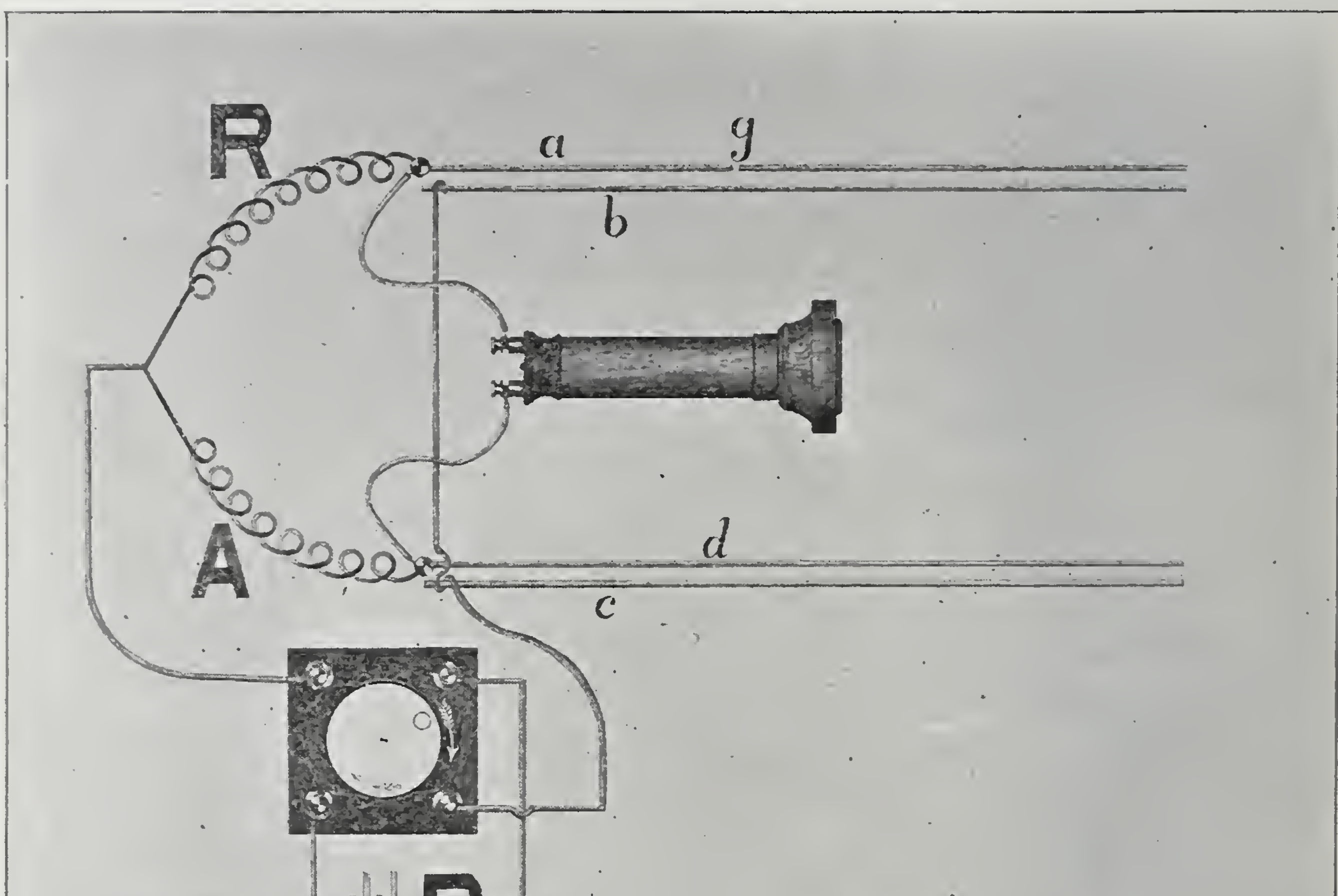


FIG. 14.

Mr. Snyder claims that his men have used this method very successfully. Figure 14 illustrates this method. In some respects it is similar to the Murry loop method for locating faults. R is the adjustable resistance and A one of the ratio arms of the Wheatstone Bridge. B is the battery, r is a reversing switch which should be made to reverse continually by a rotating motion.

a is a faulty conductor which is broken at g, and b its

mate; c is a good conductor, and d its mate; a and d are connected respectively to R and A, the terminals of the telephone being connected to the same point as shown in the diagram.

One terminal of the reversed battery circuit goes to the juncture of A and R, the other terminal of the reversed battery circuit is connected to b, the mate of the faulty wire, and to the good wire c. As soon as the connections are all made the reversing switch r is rotated, and at the same time the resistance R is adjusted until no sound is heard in the Telephone T.

Let L = the length of the cable.

$$\text{The distance to the fault} = \frac{A}{R} \times L \qquad (34)$$

When applying this test the ends of the wires a, b, c, d, must be disconnected from everything at the far end of the cable. The best values of A will depend upon the amount of battery available, and the length, and electrostatic capacity of the cable. With cables 1000 feet long, 50 or 100 cells may have to be used to give good results, and A may have to be 100 or 1000 ohms.

In applying the test to cables of large capacity or considerable length, smaller values of A may have to be used, and less battery will be required to give good results.

WHEN NO GOOD WIRE IS AVAILABLE.

Figure 15 shows the application of this method to the case of a cable where no good wire is available.

R is the adjustable resistance, A the ratio arm of the Wheatstone Bridge, T a telephone, r a reversing switch, and B the battery, K the condenser or standard of electrostatic capacity, g'' a ground connection, and g' the location of the fault.

To apply this method the connections shown in Figure 15 are made. First a balance is obtained by adjusting the resistance R so that no sound is heard in the Telephone T.

The values of A and R are then recorded, after which the

instruments are removed to the far end of the cable. Connections similar to those shown in the Figure are now made to a′. The adjustable resistance is then varied until a balance is obtained. Having recorded the new values A′, R′, the distance to the fault from the first end

$$= \frac{A \times R'}{A \times R' + A'R} \times L \quad (35)$$

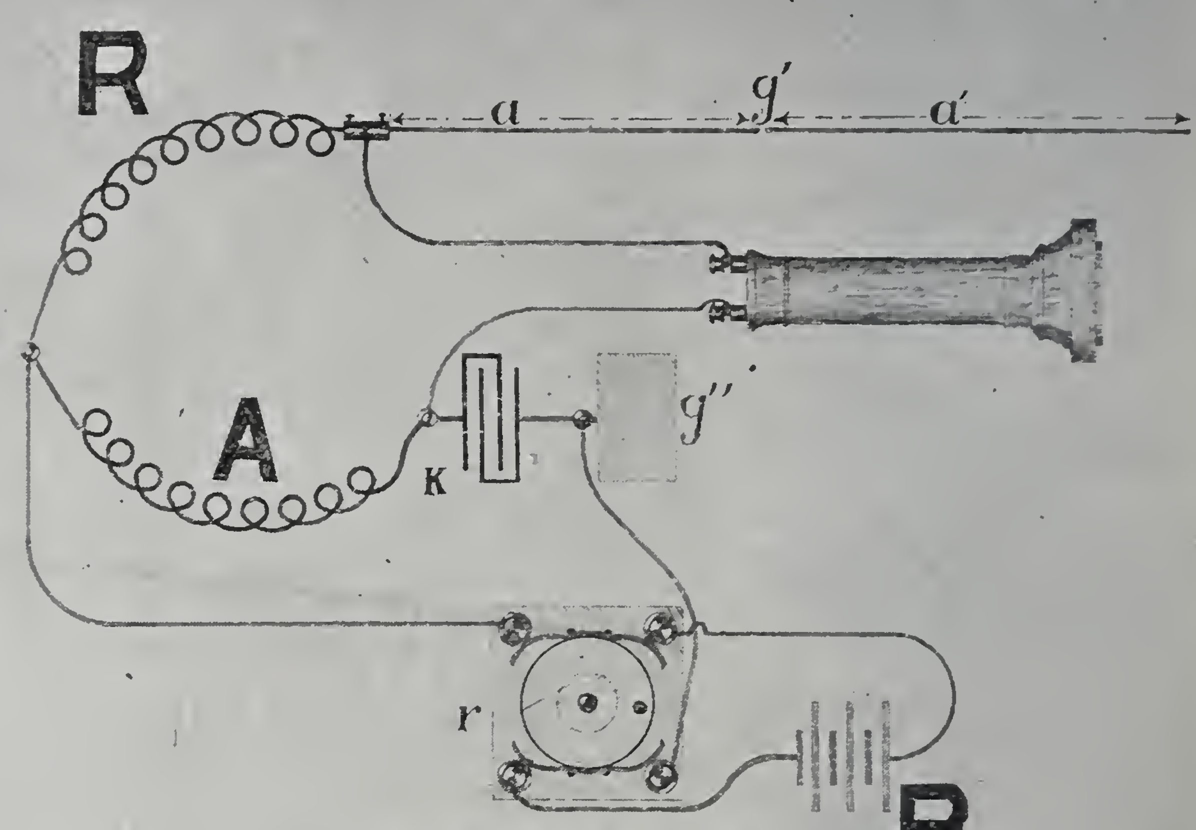


FIG. 15.

The last two general methods can be varied to suit special conditions which may occur in practice, but which cannot be treated in a paper of this kind. The Electrical World of June 27 and July 4, 11, 18, 1891, contain articles written by the writer which go more fully into special original methods for locating breaks under a variety of conditions.

TABLE SHOWING THE DIMENSIONS AND RESISTANCE OF COPPER WIRE.

B. & S. G. Number.	Diameter in Mils.	Cross Section Circular Mils.	Ohms per 1000 Feet at 68° F.
0000	460.	211600.	.04893
000	409.6	167800.	.06170
00	364.8	133100.	.07780
0	324.9	105500.	.09811
1	289.3	83690.	.1237
2	257.6	66370.	.1560
3	229.4	52630.	.1967
4	204.3	41740.	.2480
5	181.9	33100.	.3128
6	162.0	26250.	.3944
7	144.3	20820.	.4973
8	128.5	16510.	.6271
9	114.4	13090.	.7908
10	101.9	10380.	.9972
11	90.74	8234.	1.257
12	80.81	6530.	1.586
13	71.96	5178.	1.999
14	64.08	4107.	2.521
15	57.07	3257.	3.179
16	50.82	2583.	4.009
17	45.26	2048.	5.055
18	40.30	1624.	6.374
19	35.89	1288.	8.038
20	31.96	1022.	10.14
21	28.46	810.1	12.78
22	25.35	642.6	16.12

DISCUSSION.

MR. C. F. SCOTT, (Vice President in the chair)—This paper has been of special interest to those who are engaged in the electrical profession. It has attracted a number of electricians, and we have been fortunate enough to receive from them several applications for membership. In a certain way, a paper of this kind does not appeal directly to those in other professions. I suppose there are many here who have as little practical use for Mr. Fisher's paper as he has for other papers that are presented to the Society from time to time; however, it is an excellent thing for members in one line of business to hear what our members are doing in other lines. The general subject, this evening, is of interest to us. We are receiving our commodities from central stations. We receive our water through a system of pipes. We are receiving our gas through a system of pipes. Now we are receiving our electric light and power, and do our telephoning and telegraphing through systems of cables, and it is a great satisfaction to us to know when our lights go out, that there are experienced men at work in these lines who can find the trouble by scientific methods It is interesting to hear how faults can be found by these delicate instruments, and to know that they can determine, by their wizzard methods, that the error is down in a conduit in front of Smith's grocery, or some other definite place. Although Mr. Fisher has great confidence in the formula, still I think he would rather take chances upon his checker-board calculator than his formula. There is an interesting difference in the faults between electric cables and those of gas and water pipes. The water pipes may spring a leak and do no damage, with the exception of flooding a kitchen or cellar;and the gas pipe might spring a leak and do nothing worse than blow out the side of the house. If a little leak occurs in an electric cable it usually tends to destroy the insulation, so that the fault becomes greater until there is a sudden break down, concentrating in some cases hundreds of horse-

power at the defective point, which naturally produces a very serious burnout. It, therefore, becomes of great interest to know that if a little fault begins to occur, it may be detected and remedied before any violent action takes place. Mr. Fisher has given his methods for locating these errors, which are a little in advance of the text-books on this subject, and much of the data is in a more practical form than can be found elsewhere. The paper is open for discussion. It is of a character that hardly bears general discussion.

MR. FISHER—There are present several gentlemen who, if they would, could give us some valuable information on this subject. Mr. Snyder might say something of interest.

MR. R. A. L. SNYDER—I have nothing to say, as it is very late, and there is little that I could add to this subject that Mr. Fisher has not touched upon.

A MEMBER—I would ask Mr. Fisher if alternating currents, in conjunction with a telephone and a triangular coil are used in determining the location of faults?

MR. FISHER—Yes, that method has been applied, but not with very satisfactory results. It is rather difficult to find just where the point is. It was tried a good deal by the Cataract Construction Co., but was not very satisfactory.

A vote of thanks was tendered Mr. Fisher for the very excellent paper of the evening.

On motion the Society adjourned at 10.50.

REGINALD A. FESSENDEN,
Secretary.

MEETING OF THE CHEMICAL SECTION.

PITTSBURG, PA., Dec. 20, 1900.

The regular monthly meeting of the Chemical Section was held at 410 Penn Avenue, Pittsburg, Pa.

Mr. A. G. McKenna in the chair.

Minutes of the previous meeting read and approved.

The Chairman appointed the following Nominating Committee: Mr. J. M. Camp, Prof. F. C. Phillips and Mr. Rich.

On motion, the Committee adjourned to the reading room and reported the following nominees:

Chairman, A. G. McKenna.
Vice, K. F. Stahl.
Secretary, A. Gross.
Directors, Mr. Craver, Mr. Arnold.

Prof. Phillips read the paper of the evening, his subject being "The Condition of the Organic Matter in Water."

Moved and seconded that a vote of thanks be tendered Prof. Phillips for his paper, and a request that he have it published. Adjourned at 10 P. M.

GEO. O. LOEFFLER,
Secretary.

ERRATA.

In the November number of the "Proceedings" page 317, 13 lines from the bottom it should read: "The whole is then broken to pieces about one inch through," not: "one foot through."